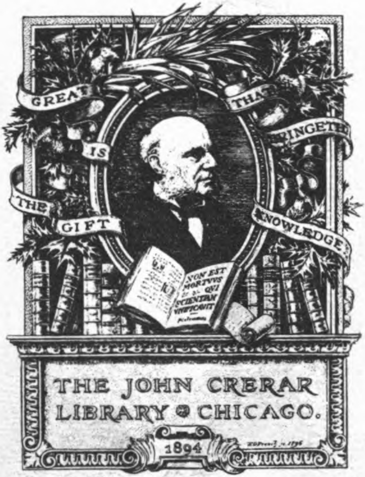
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TRAINING MANUAL, ROYAL FLYING CORPS,

PART I.

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General Staff, War Office.

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WAR OFFICE,
15*th May*, 1914.

W Graham Greene

Secretary, Admiralty.

R. H. Brade

Secretary, War Office.

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TRAINING MANUAL, ROYAL FLYING CORPS, PART 1.

CHAPTER I.—CARE OF AEROPLANES.

1. *General.*—The endurance and air worthiness of aeroplanes largely depend upon the care which is spent upon them. Aeroplanes should not be exposed to extremes of heat and cold. However well seasoned the wood may be, if it is allowed to absorb moisture, it will invariably deteriorate. Sheds, therefore, should be kept dry, and, as far as possible, at an even temperature.

An aeroplane can never be too clean. Rust, mud, dust and superfluous oil must be at once removed when it returns to the sheds. Further, an aeroplane, once housed, must have its weight supported in such a manner that there is no strain on the flexible suspension of the wheels. In this connection it must be remembered that the supports should be placed in such a position that the main weight of the machine is directly over them.

The best position is immediately under the points where the undercarriage struts meet the skids.

Before an aeroplane proceeds on a flight, and after its return, all parts, such as control and aileron wires, fabric, &c., must be thoroughly examined, and the least sign of wear in any part must be at once corrected. It is important to watch the wear of the control wires at points where they pass over pulleys or through fair leads. For a thorough examination it is necessary to remove the grease first.

All engines must be thoroughly tested before flying and after any repairs, or overhaul, have been effected.

Finally, once a week, a thorough examination must be made of all struts, internal bracing wires of fuselage, &c., with a view to checking any damage, or want of alignment.

If an aeroplane makes a forced descent, and has to be left in the open, it is important to guard against probable contingencies. The aeroplane must be placed in as sheltered a place as possible, such as a hollow, or under the lee of a hedge, facing the probable direction of the wind, and must be pegged down.

2. *Fabric.*—The following points must be understood by all:—

Fabric is protected from the damp by doping it with "emailite." Oil deteriorates both fabric and proofing material and must at once be removed as far as possible.

Portions of fabric, which are liable to get saturated with oil, will require more frequent doping than the remainder. It will also be necessary to examine the woodwork beneath the fabric. An aeroplane in fairly general use will require redoping every six months.

Holes in the fabric must be repaired at once. If the hole is small a strip of fabric can be stuck over the hole and doped. If the hole is large it will be necessary to sew the patch in.

3. *Woods.*—Although proofing materials, such as "emaillite" and "cellon," are commonly thought of in connection with fabric, it must be remembered that they also afford an excellent protection to wood from damp.

4. *Internal bracing wires.*—These must always be painted in the case of both main planes and fuselages. The colour of the paint should be light so as to show up any signs of rust.

5. *External bracing wires.*—All external bracing wires must be either painted or greased.

6. *Turnbuckles.*—These must be protected from rust by a light film of grease. They must have sufficient threads engaged consistent with safety, and must be locked.

7. *Tyres.*—Tyres are injured by oil and grease. If they come in contact with such substances they must be at once cleaned.

Pools of oil, therefore, must not be allowed to remain on the floors of sheds.

Tyres should always be properly pumped up.

8. *Engines.*—Engines must be protected, whenever possible, by means of canvas covers which should be specially made to fit. Electric cables must be fitted so that the insulating material will not be exposed to damage either by excessive heat or by chafing against some sharp edge of wood or metal. Long lengths of unsupported cables are bad and should be avoided.

9. *Propellers.*—Propellers must be protected in the same way, as exposure to damp renders them liable to warp.

As soon as flying is finished propellers must be wiped over.

10. *Bolts and nuts.*—Must be properly tightened up and locked by means of split pins or by burring the threads.

11. *Logs.*—Rough logs kept in each flight, in which all details of flights, overhauls, repairs, expenditure of fuel and oil, &c., are entered at the time the casualty occurs, are of assistance in making the fair logs an accurate history of the aeroplane and engine.

CHAPTER II.—CARE OF AEROPLANE SHEDS.

1. *General.*—All aeroplane sheds must be kept free from dirt.

Broken parts of aeroplanes or engines must not be left lying about, but must be separately stored until they can be repaired, or otherwise disposed of. Sound struts and similar parts must be kept together.

Irrepairable parts must be at once turned over to the proper store, or otherwise struck off charge and disposed of in accordance with the orders in force.

Smoking in the sheds must be strictly prohibited.

2. *Floors.*—Floors must be kept clean by the application of hot water and caustic soda. Sawdust must not be allowed as it accumulates dirt—it is only permissible in a tray to catch the waste oil from the engines.

3. *Benches.*—When aeroplane sheds are provided with benches and vices, it is convenient that the benches should be fitted with "lock-up" drawers for the storage of tools.

4. *Tool boxes.*—Places should be allotted for the mechanics' tool boxes and their contents must be periodically inspected. A list of the correct contents of a box should be pasted inside the lid.

5. *Trays.*—Every shed should have suitably partitioned trays for the reception of engine parts when engines are taken down for cleaning or repair. Parts of engines must never be left lying scattered about, or mixed with parts of other engines.

6. *Stands.*—Stands must be provided for engines to rest on when taken out of the aeroplanes.

If Gnome engines are used in the flight, it is advisable that a bench should be fixed in the shed to take the engine. This will facilitate timing, &c., before mounting the engine in the aeroplane.

7. *Clothing.*—Pegs must be provided for aviation clothing and helmets. No clothing should be allowed to lie about.

8. *Spare parts.*—Only the authorized spares may be kept in the sheds. The tendency to accumulate unauthorized spare parts must be checked. Care must be taken that spare parts, where applicable, are kept properly oiled or greased to prevent rust. Each part should bear a label showing exactly what it is and what it belongs to.

9. *Blow lamps.*—Blow lamps are not to be used except by authorized persons.

10. *Fire.*—Owing to the inflammable nature of the building, and the large value of the articles kept in it, every precaution must be taken against fire. Fire alarms must be practised in flights at periodical intervals. Buckets of sand and water and hand pumps must be kept ready filled at convenient places in each shed. One petrol fire extinguisher, such as "Petrolex," should be kept in each shed ready for use, and all ranks should know how to use this apparatus.

11. *Damp.*—Every precaution must be taken to guard against damp.

12. *Notice boards.*—A notice board should be provided in one of the sheds of each flight, on which, amongst other items, should be posted the name, address and relationship of the next-of-kin of every N.C.O. or man in the flight.

CHAPTER III.—REPAIR OF AEROPLANES AND ORGANIZATION OF WORKSHOPS.

The following has been found to be a suitable organization:—

1. *Personnel.*—The personnel available should be divided into three separate departments, with a serjeant in charge of each. The warrant officer should exercise general supervision over each department.

The three departments are:—

(*a*) Aeroplanes; hull.
(*b*) Fabric work.
(*c*) Engines, including blacksmith's, coppersmith's and welding work.

It is desirable that these departments should be located in separate buildings, but in small establishments this will not always be possible.

All mechanics must be made to realise that the greatest care and attention to the minutest details is absolutely necessary.

2. *Examination and dismantling of aeroplanes.*—This work, if it is made a matter of routine, is simple and occupies a small amount of time. The following is the system which has been found suitable:—

(*a*) In the case of serious damage or periodical overhaul, the aeroplane must be taken at once to the workshops by the men of the flight to which it belongs.

(*b*) The officer in charge of workshops then carries out his detailed examination, and prepares a statement, setting out in detail the general condition of the machine.

(*c*) The aeroplane is then stripped and all parts labelled.

(*d*) In all cases in which the machine has been in an accident the engine must be removed for a thorough examination and overhaul. For this purpose it must be handed over to the engine department.

(*e*) The parts which are not repairable are removed to the authorized place, and all small stores, such as turnbuckles, bolts, nuts, &c., which are apparently still serviceable are extracted and handed into the workshops store. In the store they are kept separate from the other spares until they have been pronounced serviceable, or otherwise, by the officer in charge.

(*f*) The parts which can be repaired and made fit for service are labelled, and sent to the department concerned where they will await their turn for repair.

(*g*) The undamaged parts are handed into the workshop store properly labelled. These should be taken on temporary charge as spare in the workshop store

until the aeroplane is again ready for them. If the aeroplane cannot be repaired the undamaged parts must be taken on permanent charge in the store account of the unit.

(*h*) All instruments requiring repairs should be returned to store, and the officer in charge of workshops should decide whether the instruments are to be returned to the makers for repair or not. In the latter case a Board must be held and the instruments struck off charge.

(*i*) Any parts of the aeroplane which require further examination before a decision as to their serviceability can be given are labelled and stored neatly together, away from the remaining parts, until they can be examined.

(*j*) Before any repairable or sound parts are handed over to their respective departments, they should be thoroughly cleaned.

3. *Repair work.* (*a*) *Engines.*—A system must be established and worked on whenever an engine is taken down for repair and reassembled. Suitable stands must be provided on which to place the engines. Trays divided up into compartments, in which to put each part of the engine as it is removed, are a necessity. It is a good system to have each compartment numbered and the parts from each cylinder, and its attachments, put into that compartment corresponding to its number in the engine.

Only in cases of urgency should parts of one engine be used to complete another. If such a course is necessary, care must be taken that the parts so used are numbered afresh so as to correspond with the numbering of the engine in which they are to be used. Thus, if No. 5 piston of one engine is to be used as No. 7 of another, it should be re-numbered 7.

When reassembling an engine the utmost care is necessary to ensure that all the parts are absolutely clean and free from grit and dirt. Petrol baths are a necessity.

Every part should also be thoroughly oiled before being replaced. Any metal part which has been bent should on no account be straightened and replaced in the engine without the knowledge of the officer in charge of workshops. As a general rule bent parts must not be straightened and used again.

(*b*) *Hull.*—Planes, while awaiting erection, must be properly supported on trestles. When the aeroplane is being erected all parts intended for that particular machine must be kept together so as to avoid using wrong parts.

(*c*) *Fabric.*—No fabric that has already been used once and doped can be used again for re-covering another plane. Care must be taken to ensure that the fabric used is free from oil. Fabric workers should work in pairs. As far as possible the fabric shop should be kept warm and dry and at a constant temperature.

4. *Care of machinery.*—Only the mechanics authorized by the officer in charge of workshops should be allowed to use the

lathes, saws, &c., with which the workshops are provided, and to start the motors for driving these machines.

With electrically driven machinery, care must be taken that all switches are "off" before the shops are closed at the end of the day. Lathes, &c., and their accessory parts must be kept properly oiled and greased, and free from rust. All belting must be provided with suitable guards. All flat-faced surfaces in lathes should be suitably protected by wood to prevent them from being damaged by tools falling on to them.

All shavings, sawdust, and metal turnings must be cleared away from the machines daily. The metal turnings should be preserved for future use or sale, different metals being kept separate.

5. *Stores and spare parts.*—No mechanic should be allowed an opportunity of making a private collection of spare parts for use in effecting repairs.

Pigeon holes should be provided for engine spare parts and various small stores, which should be labelled.

Spare parts, where applicable, must be kept greased or oiled.

When drawing new parts from the store, mechanics should, as a general rule, and if possible, hand in at the same time the corresponding broken part. Broken or unserviceable parts must not be allowed to lie about; if they are, there is

a possibility of their being used again by a careless workman. Condemned parts should be clearly marked (*e.g.*, with deeply cut cross).

6. *Storage of spare planes.*—Spare planes should be stored in such a manner that their weight is evenly supported. One plane must not be allowed to butt against another. In this connection it has been found best to suspend planes by means of canvas slings hung from overhead. Within the loop of the slings there must be a batten about 2½ inches wide. By this method the plane is supported evenly the whole way along.

7. *General remarks on organization.*—Workshops must be kept clean. At regular intervals, not less than once a week, all rubbish must be removed. Boxes should be provided in which waste metal, such as brass or steel turnings, may be kept. The benches must not be allowed to become mere shelves for an assortment of rubbish, spare parts and discarded breakages. No articles should be kept on a bench close to where some particular work is on hand, which has not a direct bearing on that work.

When an engine has been overhauled and tested it should bear a label showing date of test, time run, and number of revolutions obtained. It should then be put to one side and greased, pending the necessity arising for its use in an aeroplane. Engines must be turned by hand daily.

Log books should, if possible, be made up daily, the work actually done on each aeroplane or engine during the day being entered. Logs must invariably be made up to date, signed and forwarded at the same time as an engine or aeroplane leaves the charge of the officer in charge of workshops.

Smoking in the workshops must be strictly prohibited.

CHAPTER IV.—ASSEMBLING, ERECTING AND TRUEING UP OF AEROPLANES.

Note.—When working drawings of an aeroplane are available they must be strictly adhered to during the process of erecting and trueing up.

1. *General principles.*—(A) Selection of materials :—

Before commencing to erect an aeroplane, care must be exercised in the examination of all parts that are to be used. Attention must be paid to the following :—

Metal—

(i) There must be no signs of rust or flaws.

(ii) Only bright bolts and nuts should be employed.

(iii) Piano wire should not have been previously bent, and must be free from kinks.

(iv) Stranded wire or cable should be regularly twisted and not frayed at any point.

(v) Tubing should be perfectly straight and should not show signs of having been previously bent and subsequently straightened.

(vi) The threads of bolts, nuts and screws should be clean, and not worn or burred.

(vii) Strut sockets and other metal fittings should not be bent out of their original shape. Such fittings should also not be used if they show signs of having been bent and subsequently straightened. In the case of aluminium sockets, care must be taken that there are no cracks, especially where the sockets have been previously subjected to severe strains. Eye-plates and eye-bolts should show no signs of wear or fracture.

Wood—

The correct wood for the various parts of aeroplanes must be used. There should be no signs of flaw and the wood should be properly seasoned. Struts must be straight; any departure from a straight line runs the risk of being accentuated by end pressure to a sufficient extent to involve collapse by fracture.

Fabric—

Should show no signs of deterioration. In covering a plane, fabric that has already been doped should not be employed.

(B) Fitting of accessory parts :—

(i) All internal drift wiring and any metallic fixings covered by the fabric must be painted with some rust-resisting material, such as velure: a light-coloured paint is preferable.

(ii) In trueing up wires, the following instructions must be adhered to :—

(*a*) Turnbuckles must not be worked upon with pliers or other tools. A wire, passed through the hole provided in the barrel, must be employed, the screws being held by the fingers.

(*b*) Turnbuckles must not be shortened up to the limit of their screw threads. The wire itself must be shortened, or a new wire fitted.

(*c*) Turnbuckles must always have at least $\frac{3}{8}$ inch of each thread engaged, and as a rule must not be covered with tape.

(*d*) Under no circumstances is it permissible to saw off a portion of a turnbuckle.

(*e*) In cases where two wires which cross one another are liable to rub, they should both be bound with insulated tape at the point of crossing.

(iii) If the control wires of any machine are very long (*e.g.*, Maurice Farman), the parts which have a straight lead may be made of piano wire. All controls, however, at the points where they pass round pulleys, or through fair leads with a big change of direction, should be made of cable. In some machines, where the change of direction is very slight and fair leads are employed, piano wire, and not cable, is used by the makers.

(iv) The following general rules in regard to controls have been standardised in the R.F.C., and, in erecting aeroplanes, should be complied with :—

Engine switches of the tumbler type must be mounted to operate as follows :—

(*a*) When mounted horizontally the lever is to be pushed forward, *i.e.*, towards the front of the aeroplane for "contact" or running position, and pulled back for the "off" position.

(*b*) When mounted vertically the lever is to be raised for "contact," and depressed for "off."

Throttles, when fitted, are to be arranged so that the lever is pushed forward to open the throttle and pulled back to close it.

(v) Fitting clips on control wires :—

With this type of fitting it is usually best to employ a thimble.

When fixing the clips a blow-lamp must never be used for the purpose of distributing the solder. A soldering iron only may be employed.

(vi) All cable should be stretched before fitting.

(vii) All pulleys and fair leads for wires should be greased.

(viii) Fitting piping :—

Piping of all kinds must be arranged with a proper regard to the amount of vibration to which it will be subjected. Long unsupported lengths should be avoided. In metal piping it is generally advisable to fit a joint of specially prepared rubber tubing close to unions, as the latter frequently become a seat of fracture. Although the

special rubber tubing is prepared to resist the action of petrol and oil, it will nevertheless gradually deteriorate, and will require examination and renewal at short intervals. Chokes in pipes are frequently caused by deterioration of the lining of the tubing.

(ix) All bolts, nuts, &c., must be secured in some positive manner to prevent them from slacking back. The ordinary split pin above a nut is useless for this purpose, unless the nut is washered up to the split pin and the nut a tight fit on the bolt.

The following are the most general methods of securing :—

(*a*) Castellated nut fitted with a split pin.

(*b*) End of bolt (or stud) riveted over the top of the nut.

(*c*) Check nut fitted over ordinary nut and a split pin fitted to bear on the upper nut.

(*d*) The thread at the end of the bolt may be burred.

(*e*) Spring washers are often fitted underneath nuts, but this is not a positive lock.

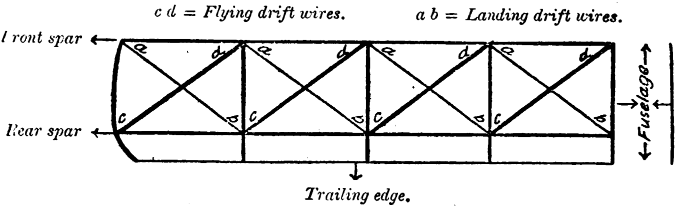
(*f*) A keep plate is sometimes fitted to the nut in the case of bolts. The bolt must, however, be fitted with a feather.

(*g*) A spring keep ring fitted round the end of a pin which has a groove cut to receive it.

(*h*) With turnbuckles. A wire passing through the hole in the barrel and secured to both eyebolts.

Turnbuckles which require frequent adjustment should be locked with steel wire, as it is more convenient to detach. Those which are not likely to require adjustment should be locked with soft iron wire.

(C) Trueing up planes, &c. Before they are covered with fabric, planes, &c., must have their main spars correctly aligned. This is done by adjusting their internal bracing wires.



PLAN.—ILLUSTRATION OF INTERNAL BRACING OF A PLANE, DISTINGUISHING THE FLYING AND LANDING WIRES.

In the internal wiring the flying wires are sometimes doubled, on account of the additional strain brought on them when the machine is flying.

The accompanying diagram illustrates the internal wiring of a plane.

(D) Covering and doping planes, &c.—Various makers use various fabrics, which differ from each other considerably.

The shrinking and preservative agents employed by various makers also differ widely. The best known amongst the latter are rubber, pegamoid, cellon and emaillite.

Two methods are employed in covering planes, and both methods have about an equal number of supporters. The two methods are :—(*a*) The diagonal method; and (*b*) the straight method. Method (*a*) is said to give the greater strength, but it is found that some makers of lightly loaded machines use method (*a*), while, on the other hand, some makers of comparatively heavily loaded machines use method (*b*).

Notes on various types.—

B.E. planes.—The fabric is sewn with needle and thread along the trailing edges and around the curved edges. It is also sewn with twine through the plane to the reverse side along each rib. Rubber solution is then thoroughly rubbed into the fabric with the fingers along each rib and rubber adhesive tape applied. Rubber adhesive tape is similarly applied around the curved ends and the trailing edges.

Dome-headed brass tacks are driven in along each rib to further secure the fabric. The planes then receive three coats of the correct emaillite solutions.

Maurice Farman.—A wire is used to support the trailing edge of the planes, and the fabric is sewn to the wire with needle and thread. The edges of the planes are finished off with tape and tacks. The fabric is secured to the ribs by flat-headed brass tacks, narrow strips of tape being employed along each rib between the fabric and the heads of the tacks to prevent the latter from drawing through the former. Special care is necessary not to draw the fabric too tight near

the straight edges of the main plane sections. Unless this precaution is observed the outermost rib will be dragged inward in a curve and difficulty will be experienced in fitting the sections of the main planes together.

Avro.—The construction of the planes of this machine allows the fabric to be carried over the straight edge and to be secured by tacks driven into the edge. When covering the outer sections of the main planes care must be taken not to stretch the fabric too much. The observance of this precaution will permit of the maximum amount of warp being obtained. The ribs are finished off with narrow linen tapes and dome-headed brass tacks.

(E) Fitting main planes.—Main planes must have their leading edges symmetrically disposed on either side of the aeroplane, that is to say :—

(i) Where the leading edges, or portions of them, have a dihedral angle they must be equally inclined to the horizontal on each side of the fuselage.

(ii) Where the leading edges, or portions of them, are to be horizontal those portions must lie in the same horizontal plane from one side of the machine to the other.

(iii) Where the leading edges, or portions of them, are set back so as to make an angle with the transverse axis of the aeroplane, that angle must be the same on both sides of the machine.

(iv) Where the leading edges, or portions of them, are to be at right angles to the longitudinal axis of the aeroplane those portions should, in plan, lie on the same straight line.

(F) **Fitting strut sockets.**—The position of the struts on the bottom plane (or sections) are first marked; two lines, one along the centre line of the main spars and the other at right angles to them, are drawn through the point where the axis of each strut meets the plane. The positions of the strut ends on the upper plane are next marked off directly from the points obtained on the top of the lower plane. This is best done by putting the top plane on the lower plane in such a position that the fore and aft centre lines of both planes correspond.

The strut sockets are then fitted into their correct positions on the main spars. Care must be taken that the sockets are correctly squared up so as to avoid any tendency to bend the ends of the struts when they are stepped into place. Thin wood packing can be used under the sockets if necessary for squaring them up.

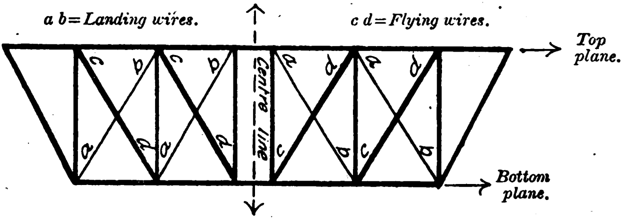
When the struts are inserted care must be taken to ensure that their ends are well home in the sockets.

(G) **Trueing up the bays between the planes and adjusting the angle of incidence.**—When the struts have been inserted between the planes the bays formed by adjacent struts both fore and aft must be trued up. The pair of diagonal wires in each bay should, as a general rule, exactly correspond. If, however, the main spars are not of the same thickness throughout (as is the case in some machines), then corresponding diagonals in corresponding bays must be equal. In checking the diagonals allowance must be made for any correct variation in the length of the struts.

If any wire is found to come too taut it is a sure sign that some measurement is wrong somewhere.

As before the flying wires are sometimes doubled, as an additional strain is brought on them when the machine is flying.

The accompanying diagram illustrates the wiring between the planes.



ELEVATION, LOOKING AFT.—ILLUSTRATION OF THE WIRING OF THE CELLS BETWEEN THE MAIN PLANES.

When checking the angle of incidence of the main planes the tail of the machine must be packed up to correspond with its flying position; this will usually be given when the engine bearer is horizontal. The angle can then be checked by finding the difference of level between the front and rear spars of the planes. In cases where cross ("incidence") wires are fitted fore and aft between the struts, the angle can be varied by tightening one cross wire and slackening off the other. If the wing is a warping one these cross wires will be absent, and the incidence can only be altered by shortening or lengthening the warp control wire itself, or by fitting suitable springs on to the control lever in such a way that a greater tension is brought on one warp wire than on the other.

(H) Adjusting ailerons. — In order to obtain correct balance ailerons must be in a neutral position, *i.e.*, in direct continuation aft of the main planes when the machine is flying horizontal and level both longitudinally and transversely.

The machine must be packed up into its flying position and the control lever lashed central (or into the flying position). The control wires should then be adjusted so that the trailing edges of the ailerons come about 1 centimetre below those of the planes to which they are attached. The force of the air stream against the ailerons will then keep the latter level with the main planes when the machine is in flight. In fitting the ailerons care is necessary to ensure that there is a proper clearance between their edges and the edge of the adjacent portion of the fixed plane.

(I) Adjustment of fore and aft balance.—Apart from the tail planes, correct fore and aft balance can only be obtained when the elevator (or elevators) is doing no work, *i.e.*, in its neutral position. The front elevator is in a neutral position when it passes through the air edge on. The rear elevator is in a neutral position when it is in direct prolongation of the tail plane. With two elevators care is necessary to ensure that one does not work against the other.

In every type of aeroplane, where they exist, tail planes must fulfil the three following conditions :—

(i) The fore and aft axis of the tail plane must coincide truly in plan with that of the aeroplane.

(ii) The transverse axis of the tail plane must be horizontal when the transverse axis of the aeroplane is horizontal.

(iii) The angle of incidence of the tail plane must never exceed that of the main planes.

With a lifting tail the fore and aft balance of the aeroplane can be altered by altering the angle of the tail plane relatively to the main planes. This can be done by varying the length of the fore and aft cross wiring between the tail struts, or, in the case in which a single tail plane is employed, by chocking up its leading edge with suitable packing. With a flat or non-lifting tail plane this latter method is dangerous, on account of the masking effect on the elevator.

(J) Checking the alignment of the fuselage in tractor aeroplanes.—The two sides of each bay formed by a pair of adjacent struts on either side of the fuselage should be equal. Adjust the cross bracing until they are. During this process it is necessary to test, with a line or straight edge, the booms forming the top and bottom faces of the fuselage. If the booms are becoming bent or distorted it is a sign that either the strut fitted is too long, or that the strut sockets have been incorrectly marked off. A final test is obtained by running a string from the centre of the forward cross sectional bay to the centre of the fuselage rear strut. The diagonals of all the cross sectional bracings should meet on this line. The cross wires, in other words, should all sight into one point.

(K) Counteraction of propeller torque.—In cases in which a single propeller, or tractor, is employed there is a tendency, on account of the turning motion of the propeller or tractor, for the aeroplane to turn about its longitudinal axis in a direction opposite to that in which the propeller, or tractor, is revolving.

There are various methods employed for counteracting this tendency. The chief are:—

Maurice Farman and Henry Farman.—The incidence wires are adjusted so as to give the main planes greater lift on the dipping side.

B.E.—A spring at the control lever exerts a greater tension in one warping wire than the other.

Racing monoplanes.—Greater surface is provided on the side tending to dip.

Avro (warping type).—Greater incidence wired on to the inner, or fixed sections, of the main planes on the dipping side.

(L) Notes on scarfing.—In the case of a fracture occurring with a solid spar, or one of the box type that is wide enough (say 2 inches), it is often possible to make a good repair by scarfing on a new length. The scarf must be long compared to the depth of the spar and the two pieces of wood forming it must be a good fit on to each other. After fitting the two halves of the scarf together they must be well glued and then clamped till the glue has set. The joint is then planed up and examined to see that it is a close one and does not have a thick layer of glue between the two thicknesses of wood. The two halves of the scarf are then bolted together as an additional precaution, large washers being employed under the bolt head and nut so as to prevent them from cutting into the wood and crushing it when tightening the nut. A waxed whipcord lashing is then served round the joint, each turn of cord being securely knotted to prevent its coming adrift. The cord may be glued finally as a further precaution.

2. *Notes on trueing up "Avro" Biplanes, Types E and Es.*—When the machine is to be assembled, the plane sections should be arranged in numerical order, according to Fig. 1 (below). These numbers will shortly be marked on the planes; at present they may be sorted out as follows:—

1. By its short length.

2. By the holes for the bracing wires which pass through to support the top plane, and by the warping joints, which come at the outer ends.

3. By the warping joints.

4 and 5. Can be distinguished by the bracing plates, which are above in 4 and below in 5.

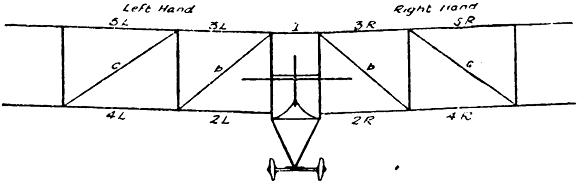


FIG. 1 (REAR VIEW).

The struts are numbered according to Fig. 2, which shows them in plan. The centre four are short, the others long.

Commence by fitting struts 1, 2, 3, and 4 to Section 1; raise the section on the struts and drop the latter into their sockets on fuselage. Tighten bracing wires sufficiently to hold in place.

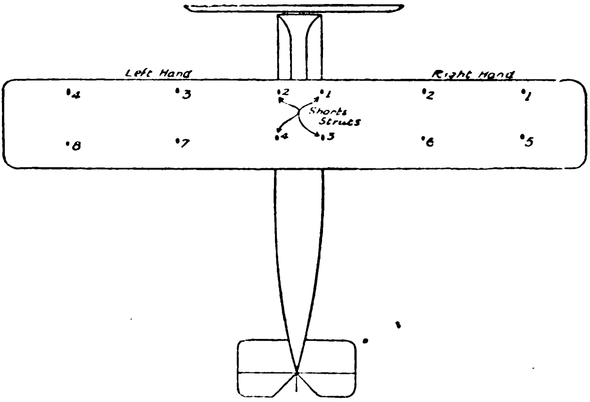


FIG. 2 (PLAN).

Fit Section 2L (Fig. 1), being careful to support outer ends until wires *b* (Fig. 1) are on, otherwise the body attachments will be strained. Fit Section 2R (Fig. 1) in the same way.

Fit struts 3 and 7 to Section 3L (Fig. 1) and raise it into position, attaching to Section 1 (Fig. 1) by clips provided. Fit Section 3R in the same way.

Attach wing-tip skids to Sections 4L and 4R (Fig. 1). (Note that these skids cannot be fitted on wrong sides, as their wiring is different.)

Fit Section 4L, observing above precautions as to support until braced by wires C (Fig. 1). Fit Section 4R in same way.

Fit struts 4 and 8 to Section 5L, and attach this section in same way to 3L. Fit Section 5R in same way.

Attach lift and warp wires but do not tighten them up.

Fit tail.—This is so simple as to need no instructions, except that care should be taken not to alter the lengths of the steel tube bracings.

Couple up all controls.

Trueing up.

On examining the *sides* of the four struts, 1, 2, 3, and 4 (*see* Fig. 3), there will be found, at the top and bottom of each, small holes ($\frac{1}{8}$-in. diameter) in positions indicated by centres of circles A, B, C and D in the figure. The bracing should be adjusted until the distances BC and AD are both, as shown in figure, 3 ft. 10 in.

This adjustment must be made on each side of the fuselage.

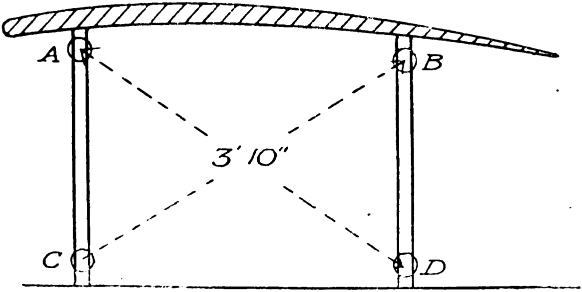


Fig. 3.

On examining the *fronts* of struts 1 and 2, similar holes will be found (*see* Fig. 4, A, B, C, D). The bracing here should be adjusted till AD = BC = 3 ft. 7 in.

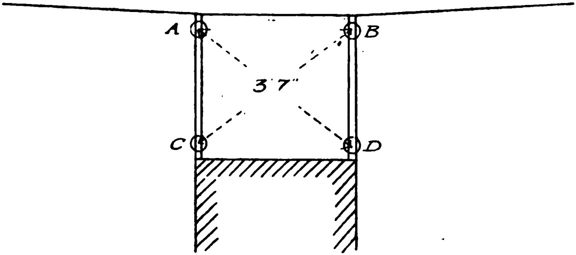


FIG. 4.

Important. While the machine is being trued up, the controls must be lashed tight, the top of the lever being $\frac{3}{4}$ *in. left of central, looking forward.* (The eccentricity is to take up the propeller torque.)

On the leading edges of Sections 3 (Fig. 1), a short distance from their inner ends, will be found small aluminium plates, each pierced with a small hole. There are similar plates near the outer ends of the leading edges of Sections 2 (Fig. 1). The gauge supplied is to be applied diagonally to these plates (Fig. 5), and the wires *b* to be adjusted until the pins fall accurately in the holes. The lift wires should then be tightened up.

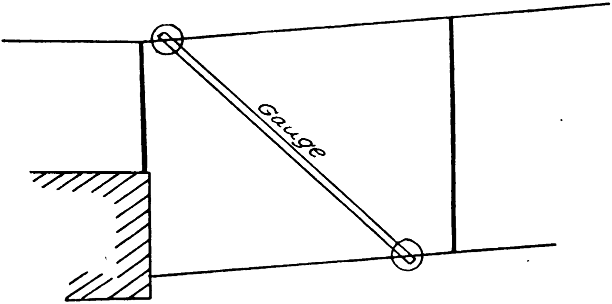


Fig. 5.

The same gauge is used in exactly the same way to true up the outer cells, gauging plates being provided at the inner end of Sections 5 and near the outside strut on Section 4.

The planes are trued for angle by the use of an adjustable level-carrier (Fig. 6). This is placed on the wing close to the body, and the leg A adjusted till bubble is central. The adjustment is then fixed and the bracing between struts 2 and 6, and 3 and 7, adjusted till the gauge shows level when placed close to these struts. This bracing and also the inner rear lift and weight bracing may then be tightened up.

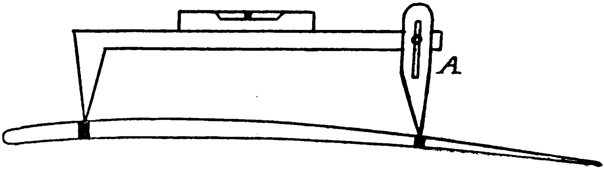


Fig. 6.

The level-gauge is then placed close to the outermost plane-struts, and the warp and balance wires adjusted till bubble is central. These may then be tightened up.

Note.—Experience only can give the correct tautness for bracing, but when the machine is at rest, the lift wires should have about ½ in. of central lateral play.

The tail angle is carefully adjusted by the makers. Small alterations can, however, be made by the adjustment at one end of each stay-tube. Larger adjustments necessitate dismantling the tail and re-affixing the attachment of the trailing edge (or leading edge, according to the date of the machine) of the fixed empennage to the body.

3. *Notes on trueing up Henry Farman biplanes* (1913 *type*).—For convenience of description the main planes can be divided up into sections as follows:—

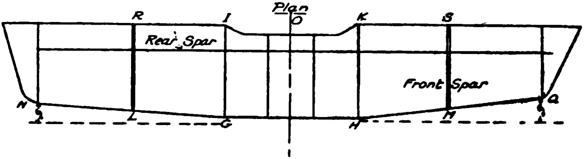
(i) Centre section GHIK (see fig.).

(ii) The right and left sections RILG and KSHM respectively (see fig.).

(iii) Extensions RLN and SMQ (see fig.).

Fig. 1

Plan



The planes are trued up in the usual manner. The spars however, are not parallel to each other throughout the entire length of the planes. In the centre section the front and rear spars are parallel. From the struts G and H the front

spars are swept back towards the outside ends 5 per cent. from the centre. This should be checked by means of a line parallel to the front spar of the centre section. The front spars, from the struts H and G are also swept upwards so that the points M and L are 23 mm. and the points Q and N 43 mm. respectively above a line drawn parallel to the front spar of the centre section.

The front spars of the extensions form a continuation of the line of the front spars of section (ii) of the top plane.

The rear spars form continuous straight lines throughout their entire length (including the extensions), *i.e.*, they are parallel to the front spars of the centre sections GHIK.

The ribs are all identical throughout the plane, except that an appropriate amount is cut off their leading end as the chord becomes smaller towards the wing tip.

The struts having been checked for length and their attachments fitted to the planes, the main cell can be erected so that the bottom plane is horizontal (by levels), both along the plane and across between its main spars. The best method of obtaining this is to fix four trestles with their top edges all level and to place the lower plane on the tops of the trestles, with its front and rear spars resting on the trestles. The trestles should come directly under the axes of the struts between the upper and lower planes.

The centre line of the upper plane is then brought directly over the centre line of the lower plane by plumb bob and the cells between each pair of front struts and those between each pair of rear struts, brought square by making the diagonal wires between the struts of equal length. The struts should all now be vertical to the planes. This can be checked by hanging plumb bobs from the upper plane in line with the axis of each strut.

The incidence wires can now be set. If both the tops and bottoms of the struts be joined by lines the latter should form, with the axes of the struts, a rectangle. Adjust the incidence (or diagonal) wires between the front and rear struts until they are equal.

Extensions.—These are fixed into place and supported by their upper wiring only. The main cell still being maintained horizontal (by level), the position of the extensions is fixed by adjusting their upper wiring till both their front and rear spars are level throughout their length. The flying wires to the extensions can then be inserted.

Tail booms.—The lower booms slope upwards, making an angle of 83* degrees with the main cell struts, but the struts between the top and bottom booms are parallel to those of the main cell. In order to fix the lower booms, keep the main cell with its struts vertical (by plumb bob) and then fix the tail booms into place, packing up their rear ends until the lower boom has the required upward slope (1 in 9). One method of checking this slope is to make a wedge of slope 1 in 9 about 1 foot long. If this be placed on one of the lower tail booms the upper surface of the wedge should be horizontal. The junction of the booms, from each side of the main cell, should lie on the centre line of the main cell produced.

Tail plane.—The tail plane is next fitted into place. Its front and rear spars should be parallel and at the same time level, *i.e.*, there should be no incidence or difference of level between these two spars. As a check the difference of level between the main spars of the main upper plane and those of the tail plane should be 30 centimetres, the tail plane being the higher of the two.

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* In some of the later 1913 Henry Farman machines this angle is increased to 84°, or a slope of 1 in 9·5.

Ailerons and elevator.—The aileron and elevator controls are so adjusted that the control is upright when the ailerons and elevator form a continuation of the planes they are attached to.

Undercarriage.—The undercarriage is then fixed on and the skids brought to their correct position in a fore and aft direction, and also parallel to each other and the centre line of the machine.

4. *Notes on trueing up Maurice Farman biplanes* (1912 *and* 1913 *types*).—**First** take the main planes, bolt them together and stick strips of fabric over the joints on the top and underneath.

Then place 8 struts—4 hollow ash, Nos. 3, 6, 11 and 14; and 4 end struts, Nos. 1, 16, 8 and 9—in the sockets of the top plane. This done, lift the plane over on to the bottom plane and fix in the remainder of the struts, attaching wires to hold the planes together.

To adjust main planes.—The centre plane should be adjusted so that the leading and trailing edges are 9 millimetres out of the horizontal in the centre in an upward direction. The remainder of the flying and landing wires should be adjusted square.

The incidence wires from back to front of the planes should be tautened sufficiently to hold the planes together.

The extensions and top ailerons should now be put on.

To adjust tail planes.—The flying and landing wires at back and front of the tail planes should be adjusted square.

Lift the main planes on to high trestles and fix on the chassis and wheels. The upright struts on the chassis should be in line with the struts on the main planes.

Then put on the front outriggers, front elevator and tail booms.

Take machine off the trestles and rest it on its wheels, putting a piece of wood under the back skids so as to just keep the springs off the floor.

Then put on the tail plane, rear elevator and bottom ailerons.

Fix the nacelle and engine in centre bay between main planes.

To adjust front outriggers.—Wire up so that the centre king post of front elevator is in line with the centre line of the nacelle.

To adjust tail booms.—See that the booms are straight (1913 type) and that the centre strut of the tail plane is in line with the centre of the nacelle. The wires in the centre bay of each tail boom should be the same length, and the other wires adjusted so that the booms are held straight.

To adjust angle of incidence.—Put the machine into flying position, *i.e.*, with top rail of nacelle horizontal.

The incidence wires should be adjusted in the following way:—

Main planes.—A horizontal line should be taken from the rear spar to the leading edge and the measurement from the leading edge to such horizontal line should be as follows:—

No. 1 strut	8·4 cm.
" 2 "	9 "
" 3 "	9 "
" 4 "	9 "
" 5 "	9 "
" 6 "	9 "
" 7 "	10 "
" 8 "	10·5 "

Tail planes.—Take a horizontal line from the rear spar of the tail plane. The measurement from the leading edge of the tail plane to such horizontal line should be 3·3 cm. (new type), 4·7 cm. (old type).

To adjust front and rear elevator.—With machine still in flying position the front elevator should be fixed horizontally.

To adjust rear elevator.—Take a horizontal line from the trailing edge of elevator to the underside of the trailing edge of the top tail plane. The measurement between the underside of the trailing edge of the top tail plane to such horizontal line should be, old type, 16 cm.; new type, 10·2 cm.

To adjust ailerons.—The ailerons should be adjusted so that the trailing edge is 15 mm. lower than the trailing edge of the main plane.

Rudders.—The rudders should be adjusted parallel with the machine.

The above directions are sufficient to correctly erect the machine, but small adjustments can be made after a trial flight.

5. *Notes on trueing up* B.E. 2 *biplanes.*—Erecting main planes.—The centre plane and its supporting struts must be erected and adjusted by means of the fore and aft wires until, with the fuselage in its normal flying position (which is given when the engine bearers are horizontal), a plumb line dropped from the top of each strut will fall 1½ inches to 2 inches behind the bottom of each strut. This will give sufficient stagger backwards to the top centre plane, and consequently to the main top planes when erected.

Time will be saved if, before fitting the main planes on to the machine, they are first put together on the floor. The right and left top planes are fixed respectively to the right

and left bottom planes, the struts put into place and all nuts screwed home. In addition, all the cables which have to be spliced to the top planes should be put into place, viz., long ends of warp wires to rear struts, the flying and landing wires in front bays and drift wires to fuselage and engine bearers. Unless data as to the correct length of the flying and landing wires are available it is not advisable to splice these wires on to the bottom planes until the top and bottom planes are fixed on to the machine. Flying and landing wires, consisting of piano wire and turnbuckles, should be inserted temporarily in each bay.

The planes are next fixed to the machine, and the temporary flying and landing wires adjusted to their correct length. The warp and anti-warp cables must then be fitted, and the splicing to the lower planes completed so as to give a temporary adjustment. The temporary wires are then cut out, except the outer bay flying wire, which should be left in in addition to the cable.

Wash out.—The angle of incidence at the wing tip is less than that at the root of the wings, *i.e.*, those portions nearest to the fuselage. This difference exists so as to minimise the self-warping effect of the wings.

The wash-out is adjusted as follows:—Stretch two cords tightly from wing tip to wing tip over the front and rear spars on top of the top plane. With the control lever central tighten up the anti-warp wires and at the same time slacken off the warp wires. Then measure the gaps at the centre between the two cords and the top plane. The gap over the front spar should be 3 inches, while that over the rear spar should be 4 inches. A rough test of the setting of the planes can be obtained by standing in front of the centre line of the

machine and looking aft—at the roots of the lower planes there should be 7 or 8 inches more of the under-surfaces visible than at the wing tips. Similarly from the back, looking at the top planes, there should be 7 or 8 inches more of the under-surface visible at the tips than at the roots.

Tail plane.—Can be adjusted by means of the ladder, or slot holes, fitted to the extreme rear end of the fuselage, so as to give more or less lift as required.

Elevators.—Care must be taken that they work in the same horizontal plane.

Undercarriage.—In trueing up the undercarriage the transverse distance between the two front struts, and also between the two pairs of rear struts where they join the skids, should be 5 feet.

CHAPTER V.—INTERNAL-COMBUSTION ENGINES.

The petrol motor.

1. *Introductory remarks.*—The object of a motor is to produce rotary motion, either in itself or in a shaft. To get this motion the motor must be provided with (*a*) a piston which must be free to move up and down within a cylinder; (*b*) attached to the piston, a rod, termed a connecting rod; (*c*) attached to the other end of the connecting rod, a crank-shaft; and (*d*) attached to the crank-shaft, a fly-wheel (or its equivalent). The action of the motor is similar to the operation performed by a man turning a grindstone. The stone corresponds to the fly-wheel of the motor, the handle to the crank, the man's arm to the connecting rod, and the power exerted in turning the stone to the exploded charge.

Power cannot be produced without a cause. One of the most effectual methods of producing power is the expansion of gases. If a substance, such as gunpowder, is exploded in a cylinder with an open end (a gun, for example) practically the whole effect of the explosion is felt at the muzzle; and, if a bullet is placed in the gun in front of the gunpowder, the former is blown out with great force. This is exactly what happens in the petrol motor—a mixture of petrol vapor and air is ignited within the closed end of the cylinder, and the force of the explosion drives the piston in front of it. The piston in moving down the cylinder carries the connecting rod with it, and the latter in its turn communicates its motion to the crank and so to the fly-wheel. The fly-wheel, once it has started rotating, will carry on its motion for an appreciable time without any further application of power. Consequently it will communicate its motion to the crank and so to the piston, pushing the latter up the cylinder again. At the same time, by forcing the piston upwards the burnt gases are expelled from the cylinder through a suitable port or valve and by an arrangement to be described later. By the action of the fly-wheel, the piston will again descend, travelling along the same path as it did when the mixture was exploded; but this time the piston is dragged instead of pushed. Immediately this dragging motion begins, the port through which the burnt, or exhaust, gases escaped is closed and a similar port, or valve, leading to the mixture and inlet pipe is opened. The downward motion of the piston produces a partial vacuum in the head of the cylinder which results in a new charge of explosive mixture rushing into the cylinder through the port which has just opened. Just after the piston reaches the bottom limit of its stroke, this port

closes. The piston is then pushed up the cylinder once more and the mixture is compressed. It may here be noted that, within certain limits, the greater the compression to which a mixture of petrol vapour and air is subject, the quicker it will burn, and consequently the greater will be the force of the explosion. When compression is at its highest, *i.e.*, when the piston is on the point of reaching the top of its stroke, the mixture is ignited and the explosion occurs, forcing the piston down.

It will thus be seen that one explosion, and consequently one power stroke, occurs every two revolutions of the crank, or four strokes of the piston. For this reason the petrol motor is described as working on the "four-stroke cycle" principle.

The four-stroke cycle can be briefly summarized as follows:—

(*a*) The piston descends, inlet port or valve opens, and the mixture is sucked into the cylinder. This is called the suction, or inlet, stroke.

(*b*) Inlet valve closes (just after the piston has reached the bottom of the suction stroke), piston ascends and compresses the mixture (both inlet and exhaust valves being closed). This is called the compression stroke.

(*c*) Just before the piston reaches the top of its compression stroke the explosion occurs and the piston is forced down again. This is called the power, or working stroke.

(*d*) Just before the bottom of the power stroke, the exhaust port opens. The piston ascends and the burnt, or exhaust, gases are forced out of the cylinder. This is called the exhaust stroke.

The cycle is then complete and the engine is ready to repeat it.

2. *Detailed description of the working of the petrol motor.* (*a*) *Arrangement of the valves.*—The majority of motors have two valves, or ports, for each cylinder—one to admit the explosive mixture, and one to release the burnt gases after explosion. The former is termed the "inlet" and the latter the "exhaust" valve or port (*see* page 43). The most common arrangement (except in rotary engines) is that in which the tops of the cylinders are cast with small extensions. In each of these extensions is a circular seating on which the head of the valve rests. The valve itself consists of a mushroom-shaped head with a long thin stem, the whole being made in one piece. The "head" has a bevelled edge which fits closely on to the seating in the cylinder, being held down by a spring mounted on the "stem." The bottom of the stem, when the valve is closed and the engine is warm, should be just clear of what is termed a "tappet rod." The tappet rod itself is raised and lowered by means of a cam, and so communicates its motion to the valve.

From the description of the cycle of operations given above, it is clear that each valve must open and close once in every two revolutions of the crank. It will therefore be seen that the cams operating the valves must be worked at half the speed of the engine. This half time speed is obtained by fixing to the crank shaft, a gear wheel with (say) 16 teeth, and providing the shaft carrying the cams with a gear wheel having 32 teeth. Then when these two wheels are in mesh, and the engine is turning, the cam shaft will be driven at half the speed of the crank shaft. Valves worked on this principle are called "mechanically-operated valves." Exhaust valves are always mechanically operated,

Inlet valves, on the other hand, are sometimes (as in the Gnome engine) automatically operated. That is to say, they are opened by the suction effect caused by the piston moving down the cylinder, the exhaust valve, of course, being closed. A light spring is fitted on the valve stem to bring it back on to its seating at the end of the suction stroke. With this type of valve it is important that the spring should be neither too strong nor too weak, and in the case of a multi-cylinder engine, all the springs should open under the same pressure. For this reason the tension of the springs is generally capable of adjustment.

Owing to the very high pressure generated in the cylinder during explosion, it is very necessary that the valves should be so designed that the pressure due to compression and explosion holds them on their seatings and so assists to keep them gas tight. For this reason valves are always designed to open inwards.

In some cases the inlet valve is placed close to, and immediately opposite, the exhaust valve so that the inlet gases pass over the exhaust valve and tend to keep the latter cool.

Valve settings.—The valve settings on an average internal-combustion engine are as follows:—The angles given below are the positions of the crank arm for each position of the valves for any particular cylinder. (*See* Fig. 1.)

Commencing the cycle, the inlet valve opens on the induction stroke at a point when the crank is about 5° to 9° past the top dead centre. It remains open until the crank is about 18° past the bottom dead centre (in some fast running engines this angle is very much bigger).

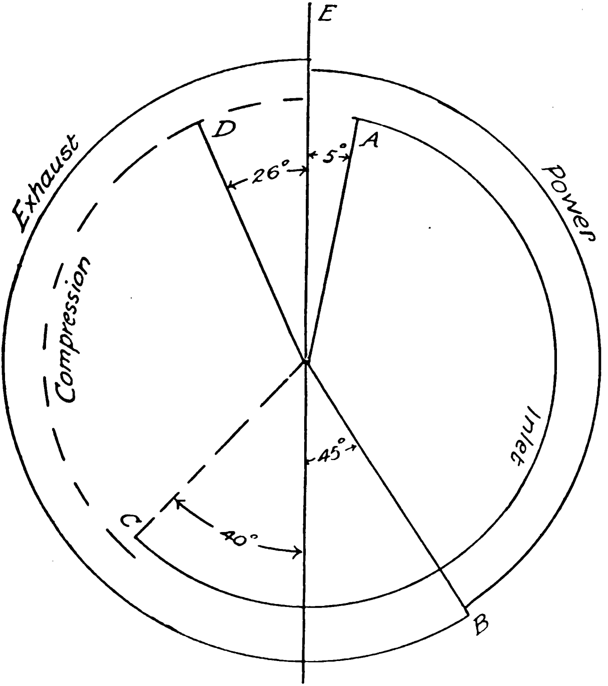

FIG. 1.

A.—Inlet value opens at 5°.
B.—Exhaust valve opens 45° to 75°.
C.—Inlet closes 40° past bottom of stroke.
D.—Sparking occurs at 26° (variable while running).
E.—Exhaust valve closes at top of stroke.

VALVE SETTINGS.

The piston ascends and the gases are compressed, and, at a variable point (normally about 26°) just before the crank reaches the top dead centre, the charge is ignited. Expansion of the gases now follows until the crank has reached a point varying between 45° and 75° before the bottom dead centre. The exhaust valve then opens and the gases rush out. This early opening is called "giving lead" to the exhaust valve, and it is found very advantageous, as it ensures an effective escape of the exhaust gases and consequent absence of pressure against the piston on its return stroke. If the "lead" given to the exhaust valve is insufficient, the engine is liable to overheat.

The exhaust valve remains open during the whole of the exhaust stroke, and closes when the crank has gone about 1° to 5° past the top dead centre.

All valve settings must be taken with the engine turning in the ahead direction, so as to avoid any errors due to play in the various gear wheels, &c. If the engine be turned too far ahead past any particular setting, turn it back more than the amount required before starting to take the readings again.

In order to obtain the direction of revolution of an engine, turn it by hand. The inlet valve will open directly after the exhaust valve closes, if the engine or crank shaft is being turned in the correct direction. By watching the inlet valves, the order in which the cylinders fire can be determined.

When parting an engine for examination and repairs it is absolutely necessary to note most carefully the relative positions of the timing gear wheels. They should be marked

unmistakably (usually done by the makers) so that they can be put back in exactly the same relative positions as those in which they were found.

(*b*) *The piston.*—The piston can be described as a hollow cylindrical plug, to the interior of which is hinged the connecting rod. This is done by means of a short circular steel crossbar, called the "gudgeon pin," which is set diametrically through the piston and secured firmly to it. It is important that the gudgeon pin be held firmly in the piston and also in the lugs holding it to the piston.

The piston is made of slightly smaller diameter than the cylinder (from $\frac{4}{1000}$ to $\frac{6}{1000}$ in.) in order that it may move freely up and down within the latter. This being so, it is evident that if other arrangements were not made, the gases would leak past the piston, resulting in a considerable loss of compression. This difficulty is surmounted by cutting one or more grooves round the outside of the piston wall, into which "piston spring rings" are fitted. These rings are made of slightly larger diameter than the bore of the cylinder, and are cut through, sometimes diagonally and sometimes in the form of a step. Thus, when the piston is in the cylinder the rings are compressed. At the same time they are constantly trying to expand to their normal diameter, with the result that they press tightly against the cylinder walls and keep the piston gas tight. When two or more rings are employed the slits in the rings must not be vertically over each other. They must be set in different positions round the piston, so as to avoid as far as possible the escape of any gases past the slits as would occur were they in line. The ends of these rings must be some distance apart when cold ($\frac{1}{32}$-in. for a 4-in. piston) so as to allow for expansion when the rings become hot.

(*c*) *The carburetter.*—This term is applied to the apparatus which is responsible for the regular supply of explosive mixture to the cylinders. One of the most important factors in the efficient running of a petrol motor is the mixture. It is essential that the particles of petrol vapour and air should be mixed as intimately as possible before they reach the cylinder. This is what the carburetter does. (*See* Fig. 2.)

The petrol is lead from the tank into what is termed the "float chamber." The object of this chamber is to keep the head of petrol at a constant level. Inside the chamber is a hollow brass float. Through the centre of the float a needle passes, which, when the petrol has risen to a high enough level in the chamber, fits down into a seating in the petrol pipe, thus cutting off a further supply. Just above the top of the float two balance weights are attached to the needle. The weights are pivoted about the needle and rest on the top of the float. Thus, as the level rises in the chamber, the weights are pushed up, and eventually allow the needle valve to fall back on to its seating, and so stop the supply of petrol. When the level of the petrol in the float chamber falls the float drops, and the balance weights, acting on the needle valve, lift it, and allow a fresh supply of petrol to come from the petrol tank. Means are provided for lifting the needle off its seating by hand, with a view to flooding the carburetter before starting the engine. Carburetters must never be "tickled," as this wears the needle, making it a bad fit on its seating. The needle must simply be lifted until the carburetter floods, and then dropped.

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A small pipe leads the petrol from the float chamber into the "jet chamber." Screwed into the end of this pipe is a vertical jet or nozzle (a set of jets with different sized orifices can be obtained for use under varying atmospheric conditions). When the engine is running, a partial vacuum, due to the suction effect of the engine, occurs round the jet, and, as the latter is small, the petrol is emitted in a fine spray, a condition which makes vaporization easier, and consequently admits of more perfect mixing with the air being sucked past the jet. In some carburetters the vaporization of the petrol is further assisted by warming the supply of air to the carburetter, or jacketing the inlet pipe with hot air or water.

An inverted double cone is sometimes fitted round the jet to increase the speed of the air past it, thereby still further reducing the pressure at this point. This also causes the difference of pressure on the petrol in the float chamber and on the jet orifice to be increased, resulting in an increased flow of petrol without interfering with the fineness of the spray.

From the jet chamber the mixture passes along the induction pipe to the cylinder.

The action of the float can be likened to that of the automatic water cistern with its ball valve, while the action of the jet can be compared to that of a scent spray.

(*d*) *The throttle and air valve.*—The induction pipe is provided with a tap, called the throttle, by means of which, the amount of mixture admitted to the cylinders can be regulated. The more this tap is opened, the greater will be the quantity of the mixture admitted and the faster the engine will run. But the faster the engine runs the

greater will be the suction effect at the jet. Consequently the mixture will become richer in petrol, unless some means are employed for admitting more air. This is usually done by making the throttle act on both the inlet and discharge sides of the jet, or else by providing an additional air port, the size of which, and therefore the quantity of air admitted, can be varied at will. Another method is to provide the extra air port with a spring which allows the port to open wider as the suction in the inlet pipe increases.

(*e*) *Lubrication.*—The lubrication of bearings is carried out by the formation of a very thin film of oil between the moving surfaces, which must be truly aligned and worked to a smooth surface, otherwise the oil film will be broken at the "hard places," where the metal will become scored and the bearing probably overheated.

This film of oil is formed by the relative motion of the surfaces, and the higher the relative velocity and the more viscous the oil, the more stable will the film become.

At low speeds, especially under heavy loads, the oil film is liable to be squashed from between the bearing surfaces, and the lubrication will then largely depend on the "greasiness" of the surfaces; for this reason slow moving toothed wheels are better lubricated by a thick grease than any sort of oil.

At high speeds, the film of oil will form between the moving surfaces even if the oil is fairly thin; but if the load is great the lubricant must be of a more greasy nature.

The animal and vegetable oils (*i.e.* castor, sperm, &c.) are more greasy than the minerals, and so must be used under heavy loads even where the speed is high. If, however, the oil is forced through the bearings under pressure, and is

required to remain in contact with the working parts and to be used over and over again, mineral oils must be employed. Under these latter conditions vegetable and animal oils become acid and gummy, and are therefore unsuitable.

Water is a very bad lubricant, since it is not viscous enough to form a film between moving surfaces, nor is it greasy, and so great care should be exercised to exclude it from all working surfaces.

The oils more commonly used are enumerated below. They all weigh rather less than water. The vegetable and animal oils are liable to "gum" by oxidation, but mineral oil is free from this defect and can be used again and again, provided it is filtered each time before re-use. For these reasons mineral oil is employed for lubrication of all internal-combustion engines with the exception of the Gnome and one or two other types, where the oil simply passes through the engine and then escapes.

Mineral oil (light)	For forced lubrication of bearings and low-powered internal-combustion engines (water-cooled).
Heavy filtered mineral oil ...	Large internal-combustion engines (air-cooled).
Mineral grease, vaseline ...	For preserving machinery and also the lubrication of gear boxes, &c.

With internal-combustion engines, since the oil comes into contact with very hot surfaces, such as the piston, &c., an oil with a flash point of over 250° Fahr. should be used; a fine mineral oil which is suitable for all bearings and working surfaces is generally employed.

The different methods employed for lubricating petrol engines are many, but they can be classed generally under two heads:—

(*i*) *Splash lubrication.*—In this method the engine is started with oil in the crank case up to a certain level; additional supplies of oil are pumped into the crank case periodically when the engine is running. The crankpins of the engine revolve in the oil in the crank case and splash it up to the piston and cylinder walls, &c. A baffle is usually fitted at the bottom of the cylinders, leaving just sufficient room for the travel of the connecting rod. This prevents over-lubrication (and so carbonization) of the piston and cylinder walls and sooted plugs.

(*ii*) *Forced lubrication.*—In the forced lubrication system the crank pit, or case, contains a certain amount of oil, which, by means of a pump, is delivered to the main bearings, thence by means of holes through the crank shaft to the crank head bearing, and then by a pipe or grooves along the connecting rod to the gudgeon pin bearing. A separate lead also supplies the cam shaft and bearings and its gear wheels. The oil streams into all the bearings and keeps them well lubricated, so that, if well fitted, there is extremely little wear in any of the bearings thus fed.

The oil used is mineral. As it is circulated round the system and used over and over again, it is necessary to filter it between each "round" through efficient strainers, so that no carbon or other foreign substance is forced into the bearing. Any grit (carbonized oil, &c.) in the lubricant would of course at once produce local heating of the bearing.

A pressure-gauge is provided with this system, and from 5 to 55 lbs. pressure per square inch is maintained by the pump according to the type of engine. Should the pressure fall below this, it is usually due either to the strainer getting choked and checking the supply of oil, or to the level of the

oil in the well falling too low and causing loss of suction. When this occurs more oil should be immediately supplied to the crank case. It may here be noted that the pressure shown when the engine is first started will be considerably above that which may be expected after the engine has been running long enough to heat the oil.

(*f*) *Silencer.*—At the end of the working stroke there is always a pressure in the cylinder above that of the atmosphere, and whenthe exhaust valve opens the gases rush out into the surrounding air at a high speed and with much noise. To reduce the noise a silencer is usually fitted, consisting essentially of a large vessel, into which the waste gases pass direct from the engine. This vessel has a comparatively small exit hole for the gases to escape through to the atmosphere; the result is that, instead of rushing into the air with a series of loud reports, they escape in a steady stream. Baffle plates are often fitted in the silencer. The silencer reduces the power of the engine on account of the obstacles the gases meet on their way to the air; consequently, the piston has to do more work in forcing them out of the cylinder. In some engines it is possible, however, to fit an exhaust pipe in such a manner that one cylinder's exhaust assists another cylinder's exhaust.

(*g*) *Ignition.*—There are two types of ignition arrangements —(i) accumulator; and (ii) magneto.

(i) *Accumulator ignition.*—This system has largely been superseded by magneto ignition, but owing to the fact that it gives practically a continuous spark without the assistance of the engine, it is retained in many motor car engines to facilitate starting when the engine is cold.

An accumulator must not be left uncharged for a long time as it will "sulphate," or become choked with a white deposit, which ruins it. Never let the level of the acid get below the top edge of the plates—add distilled water. Never short-circuit the accumulator by placing a wire or piece of metal across the terminals to see if it gives a spark. If the acid is muddy and there is a considerable amount of deposit the accumulator is in bad condition. When the condition is good the plates should be a good dark brown and slate colour respectively, and the acid clear.

The celluloid casing of accumulators is easily damaged, and care must be taken, when fitting accumulators in boxes, that the casings are protected against rubbing on sharp corners, bolts, &c.

To test for current, connect a 4-volt lamp across the terminals and note if the lamp gives a bright light; or use a voltmeter. The voltage should not be allowed to get below 3·8. A *new* accumulator should be recharged after a slight decrease in efficiency instead of being allowed to get down to the lowest voltage. To avoid corrosion, do not allow any acid to remain on the top of the case, and coat the terminals with vaseline.

As a substitute for an accumulator, "dry batteries" are sometimes used. These are made in many different sizes, but, briefly, they all consist of a carbon rod placed in a zinc casing, the space between being filled with a chemical preparation which varies in detail with different manufacturers. The current is obtained as a result of chemical action between the components of the cell. No charging is necessary.

Dry batteries are called "primary" batteries, and accumulators "secondary" batteries.

In order to obtain a high-tension spark from an accumulator an induction coil must be employed. It consists of a bundle of soft iron wire, around which is wound about 20 feet of thick wire. This is called the primary winding. One terminal of the battery (usually the positive) is led to the bed plate of the engine, and so forms what may be termed an "earth." The other terminal is connected, through what is known as the "contact breaker," to one end of the primary winding. The other end of the primary is led to a brush, which bears on a "commutator" keyed on to the cam shaft of the engine. This commutator has one metal strip let into it for each cylinder that must be fired. When the brush bears on these strips the end of the primary circuit earths to the engine bed, thus completing the battery circuit, and the current flows through the primary winding.

Round the primary winding, a second insulated wire, about 1½ miles in length, and of very much smaller diameter, is wound. This is called the "secondary winding." When the current passes through the primary winding the iron core of the coil is magnetised and a current is induced in the secondary winding. At the same time, by using the magnetism of the iron core, the primary circuit is broken at the contact breaker. When this occurs a current is again produced in the secondary winding, but, owing to the influence of this latter current the current in the primary winding only dies away slowly, and maintains its original direction. If no other means were employed the induced current in the secondary would not be sufficiently intense to produce the high-tension spark required to ignite the mixture. To get over this difficulty a "condenser" is employed, consisting of a box containing a number of metal strips carefully insulated from each other. The condenser is joined up to the two sides of the

contact breaker, and through this to the poles of the accumulator. Thus, when the primary circuit is broken, the condenser instantaneously absorbs the current from the accumulator, and becomes charged to a higher voltage than that of the cell terminals. To obtain equilibrium, the current surges back and produces practically an instantaneous reversal of the current in the primary winding. It is this sudden reversal of current which produces in the secondary circuit the very high voltage necessary to give the spark. One end of the secondary circuit is earthed, and the other is joined to the "sparking plug" (through the distributor, see below). When the current occurs in the secondary it is so intense that it will jump across the plug points and thus complete the secondary circuit to earth.

Having got the current which will produce a spark the next problem is—How is it to be conducted to the correct cylinder? The secondary current is first led to a collecting ring termed the "distributor," which is worked off the same shaft as the commutator. This ring carries a brush, which, as it revolves, distributes the current to insulated metal strips, which are, in their turn, connected to individual cylinder plugs.

The accompanying diagram (Fig. 3) illustrates accumulator ignition and its connections.

(ii) *Magneto ignition.*—The fundamental principle on which the magneto works may be expressed simply as that in which a closed coil of wire rotates within the field of force of a magnet and cuts through lines of force. A current is induced twice per revolution of the coil.

The field of force exerted by a magnet is easily demonstrated by placing a sheet of paper over the poles of the magnet and then sprinkling iron filings on the paper. The filings will take up clearly defined positions around the poles.

facing p. 58.

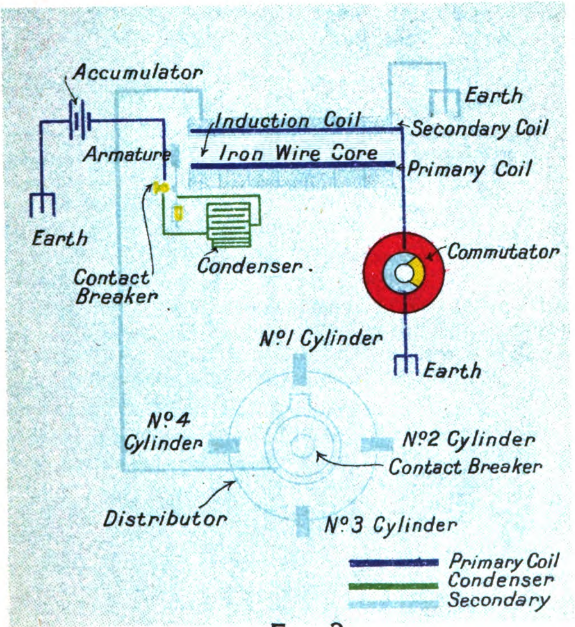

FIG. 3.

ACCUMULATOR IGNITION

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Magnetism is produced by an electric current; in fact, when a current is passed through a conductor a magnetic field of force is produced. Similarly, an electric current can be obtained with the help of a magnet. This can be seen very simply by winding insulated copper wire round a hollow conductor and joining the ends to a galvanometer (an instrument used for detecting an electric current). A powerful bar magnet is then plunged into the interior of the coil. The galvanometer will at once show the presence of a momentary current. If the magnet be as suddenly withdrawn another current will be produced. The important point is to have relative motion between the magnet and the coil; it does not matter whether the magnet or the coil is stationary.

Some metals retain their magnetism permanently, whilst others lose it at once. An example of the former is hardened steel, and of the latter soft iron; advantage is taken of this fact in the magneto.

The magneto consists essentially of two or more horseshoe-shaped magnets placed side by side (in some magnetos there is a pair of double magnets side by side, and in which one magnet is placed on top of the other). The ends of the magnets are termed "poles," *i.e.*, north and south. Attached to the poles by screws are pieces of very soft cast iron, which are cut away into semi-circular form inside the horseshoe. It is across this "polar space" that the magnetic lines of force are concentrated. Within this horseshoe, and the semi-circular pole piece, an "armature" is made to rotate. This armature consists of a shuttle-shaped core around which primary and secondary windings are coiled exactly in the same manner as in the induction coil for

accumulator ignition. As the armature rotates in the magnetic field it is evident that there are two positions in each revolution when the coils are being cut by the largest number of lines of force. (Fig. 4.)

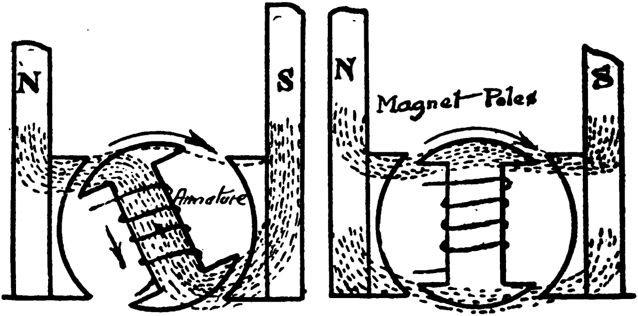


FIG. 4.

"MAXIMUM POSITION"—LINES OF FORCE CUTTING PRIMARY AND SECONDARY WINDINGS.

LINES OF FORCE PASSING THROUGH CORE OF ARMATURE.

These are called the "maximum positions," and it is at these points that the current is induced in the primary winding. A new field of force is then created due to the current passing through the primary, and this field is further strengthened by the core of the armature becoming itself a magnet. These new lines of force cut the secondary winding and induce a current in that, adding still another

"field." The current in the primary is then broken at the contact breaker and the field belonging to the primary collapses, but slowly, owing to the influence of the lines of force of the secondary, the current still tending to flow in the same direction. At this point the condenser comes into play in the same manner as in accumulator ignition, and a sudden reversal of the direction of the current in the primary occurs. So rapidly do these motions take place that the spark occurs at the plug at the same instant as the breaking of the primary circuit. It is thus seen that two sparks are obtained every two revolutions of the armature, and the speed of rotation therefore has to be regulated according to the numbers of cylinders in the engine.

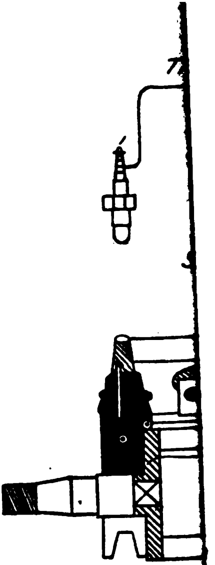
Although there are only two positions in which the maximum number of lines of force cut the armature windings, yet immediately before and after these positions are reached there will still be enough lines of force cutting the primary to give a current. It is this fact which allows the ignition to be advanced or retarded at will.

The primary current is broken mechanically by a fibre stop on the end of a bell crank lever (*g*1, Fig. 5) carrying one half of the contact breaker. Rollers are fixed in the circular track passed through by the fibre stop in its revolution, and, as the stop passes them, the bell crank lever is swung about its fulcrum, parting the two screws forming the sides of the contact breaker. One end of the primary circuit (*c*1, Fig. 5) is earthed to the armature core and the other connected to the fixed half of the contact breaker (*g*2, Fig. 5), which is carred on the armature spindle. The secondary circuit (*c*2, Fig. 5) is usually connected to one end of the primary, so as to get earth. The other end

is connected to a slip ring, where a brush collects the secondary current produced by the rupture of the primary current, and passes it on to the distributor (*n*1, Fig. 5) and thence to sparking plugs. The distributor is on the same principle as that described above for accumulator ignition. The condenser (*d*, Fig. 5) is connected in parallel with the two sides of the contact breaker, *i.e.*, the two plates are connected to the two parts between which the break in the electrical circuit occurs.

To protect the insulation of the condenser from being pierced by the high voltage when one of the leads to the plugs is withdrawn, a "safety spark gap" (*k*, Fig. 5) is provided near the brush collector on the slip ring. This acts as a sort of "safety valve," for, as soon as the voltage, or "electrical pressure," rises too high, a spark jumps across this spark gap, thus relieving the electrical pressure in the circuit. To stop the flow of current to the plugs, in order, for instance, to stop the engine, the end of the primary winding leading to the contact breaker is connected by a carbon brush to a switch. By "closing" the switch this end of the primary winding is put to "earth," and the coil is thus turned into a closed circuit. Hence no make and break can occur in the primary, and so no current is generated in the secondary circuit. When, however, the switch is "open," the contact breaker again comes into action, and the magneto, if revolved, will give a spark. A terminal (*r*1, Fig. 5) is always provided for this purpose on the magneto.

(*h*) *Cooling.*—Since the explosion takes place inside the cylinder itself, and the temperature reached by the gases is very high, the cylinder walls have to be cooled by some external means, in order to prevent them becoming too hot.



Ex

*c*1—*Prin*
*c*2—*Seco*
d—*Cond*
*g*1—*Bell*
*g*2—*Long*
*g*3—*Shor*
k—*Safet*

The effects of overheating are:—

(i) The metal is weakened very considerably, so that all parts would have to be very much thicker and heavier in order to prevent distortion or fracture.

(ii) The lubricating oil is burnt up, and the cylinder scored by the deposit of carbon; also there is a very great risk of one or more of the pistons "seizing up" in the engine and stopping it.

(iii) The charge may explode, or pre-ignite, during the compression stroke, entailing a corresponding loss of power.

One of two methods is usually employed for cooling the engine. The alternative methods are (A) water cooling, and (B) air cooling.

(A) *Water cooling.*—Jackets, through which water is kept circulating, are cast round the cylinder walls and ends, also round the exhaust valve seatings. The hot water from the jackets is led to a radiator, which dissipates the heat to the atmosphere. This cools the water so that it can be used again. The usual method employed for circulating the water, especially with fast running engines, is to force the water through the jackets by means of a circulating pump driven by the engine itself.

In some cases the water is circulated automatically on the thermo-syphonic principle, in which the fact that hot water is lighter than cold, and therefore rises to the top, is used.

The design of the engine should admit of no chance of air or steam pockets forming, which might prevent a

steady flow of water through the system. To prevent these pockets, a small air cock is usually fitted at the highest points of any bends, &c. Small pipes are also often led from the tops of all such bends in the circulating water piping to the radiator, to carry off any steam formed when the engine is running fast. Provision must be made for completely draining the jackets after using engines during a spell of cold weather, so as to avoid any chance of bursting the cylinder, jackets, pipes, &c., due to the water freezing.

All cooling, though very necessary, is extremely wasteful, some 30 to 50 per cent. of the total heat given out by the combustion of the fuel being carried away by it. (*See also* Efficiency, page 65).

(B) *Air cooling.*—In many petrol engines the cylinders are kept cool by means of a stream of air impinging on their outer surfaces. In order to assist this dissipation of heat, gills or fins are formed on the outside of the cylinders, which add to their external surface and so increase the rapidity of heat diffusion. Where the cylinders are small, the heating surface per unit volume of cylinder capacity is sufficiently large to give cool running without other means than the ordinary rush of air past the cylinder due to the motion of the body. The larger the diameter of the cylinder, the less will be the surface per unit volume. Larger cylinders will therefore require some additional means of cooling them, such as:

In the Renault engine, a fan, which forces air into a casing between the cylinders. The air escapes out of the casing past the cylinders, and in doing so cools them.

In the Gnome engine the cylinders are kept cool by rotating them rapidly through the air.

One of the chief difficulties that have to be contended with in an air-cooled engine is overheating of the exhaust valves. It is sometimes found convenient (*e.g.*, Wolseley engines) to provide a water jacket round the valve-box, and stem guides to keep these parts cool. The extra weight entailed is small, and is, on the whole, quite justified by the results obtained. In some engines the inlet valves are placed close to and opposite the exhaust valves, so that the incoming mixture passes over the exhaust valves, thus tending to keep them cool.

(*i*) *Efficiency of the engine.*—The petrol engine is simply a heat engine. It is supplied with heat in the form of fuel, and each pound weight of the fuel gives up a certain definite amount of heat when it is completely burnt. The amount of heat in, say, 1 lb. of fuel can be accurately determined by actual experiment, 1 lb. of petrol being found to give up, when completely burnt, about 22,000 British thermal units of heat.

If a motor-tyre be pumped up, the temperature of the pump barrel will rise, but this is not entirely due to friction inside the barrel. In compressing the air work is done, thereby generating heat; if now the air is allowed to expand again to its original volume, by passing through a small orifice, it gets a high velocity, *i.e.*, work is done by the air on itself, and it becomes cool again. This is exactly what happens in the petrol engine. The explosion of the mixture generates a pressure, which gives the heat a means of doing work, and so transforming the thermal units obtained from the explosion into mechanical work. For every 778 ft.-lbs. of work done on the piston, one British thermal unit will

have to be abstracted from the hot gases in the cylinder to supply the energy necessary for this work done.

The most usual way of expressing the efficiency is as a percentage of the heat available in the petrol used that is turned into useful work by the engine.

The total heat received by the engine is dissipated in four ways:—

(1) Part does useful work on the piston in the cylinder;

(2) Part escapes with the exhaust gases during the exhaust stroke;

(3) Part goes into the cooling-water system (or to the surrounding atmosphere if the air-cooling system is used), provided to prevent the cylinders getting too hot, and so gets lost so far as the useful work of the engine is concerned;

(4) A very small part is lost by radiation; this may be neglected in comparison with the losses due to (2) and (3).

The efficiency will therefore depend on the magnitude of Nos. (2) and (3).

In order that these losses may be reduced to a minimum, *i.e.*, in order to obtain the maximum efficiency, it is necessary:—

(*a*) To have a mixture of correct strength and properly mixed;

(*b*) To have as large a ratio of expansion as possible consistent with the avoidance of pre-ignition during the compression stroke;

(c) To advance the spark sufficiently far to ensure the completion of explosion just before the commencement of the working stroke;

(d) The temperature of the cooling-jacket water should be kept as high as possible consistent with cool running.

These conditions will now be examined in detail:—

(a) Too rich a mixture, and also too weak a mixture, cause a slow rate of explosion. The component particles of the explosive charge will not mix sufficiently well to get rapid combustion; the flame of explosion will consequently only travel slowly through the charge. The result is that, by the time the explosion is finished, the piston will have completed a considerable fraction of its working stroke, and the actual flame of explosion will therefore come into contact with a very large area of the cylinder wall. A large proportion of the heat will consequently be conducted through the cylinders into the water jacket.

(b) When the piston is on its working stroke it is receding from the gases in the cylinder head; the gases therefore expand and cool down. Consequently, it is necessary, in order to get them as cool as possible before being exhausted, that the working stroke should be as long as possible. The travel of the piston is the same on the compression as on the working stroke, and the maximum ratio of expansion is practically the same as the maximum ratio of compression. Hence it follows that the maximum ratio of expansion is obtained when explosion is completed, just as the piston starts on its working stroke. At the same time it will be seen that with this condition of maximum ratio of expansion there will be a minimum loss of heat to the cooling system.

for, when the gases are at their highest temperature (*i.e.*, when explosion is just completed) they will be in contact with the minimum area of cylinder walls.

(*c*) It must be remembered that, compared with the movement of the piston, explosion takes an appreciable time to complete. In order therefore that the explosion may be completed by the time the piston reaches the top of its stroke, ignition must occur at the latter end of the compression stroke, *i.e.*, the spark must be advanced. With the spark advanced and the mixture still being compressed, explosion takes place very rapidly, and therefore the gases, when at their highest temperature, are in contact with the cylinder walls for the minimum length of time. If, however, the spark is advanced too far, *i.e.*, with ignition taking place very early in the compression stroke, explosion will be completed before the piston reaches the top of its stroke, and a very much larger loss of heat to the cooling system will result: if the advance is very excessive, the explosion will tend to prevent the piston from reaching the top of its stroke.

(*d*) The amount of heat conducted from the cylinders into the cooling system will depend, *inter alia*, on the difference of temperature between the cylinders and the cooling system. The larger the difference, the greater will be the amount of heat lost.

3. *Defects, their causes and remedies.*—There are three essential conditions to be fulfilled in order that an internal-combustion engine may be started and then be able to carry on working. These are:—

(1) The mixture must be of the correct strength, and its components properly mixed.

(2) There must be sufficient compression to bring particles of the mixture into intimate contact with each other, and so render them explosive.

(3) There must be some method of igniting the charge at the right time of the stroke, *i.e.*, somewhere near the end of the compression.

If the engine refuses to start after flooding the carburetter, opening the air inlet and switching on the current, or putting other ignition devices into gear, &c., proceed to test if all these conditions are being fulfilled, as follows:—

(1) *Faulty mixture.*—A frequent trouble with the mixture is due to omission to turn on petrol, or to the petrol pipe being choked. Examine the petrol pipe and filter, and clean if necessary. If the petrol be pressure fed, there may be insufficient pressure in the tank to force the petrol into the float chamber of the carburetter. In any case of the engine refusing to start, or suddenly stopping, always *first look* to the petrol supply by ascertaining if the carburetter will flood. A choked spray, or water in the carburetter, may also be the cause of the trouble. Examine, and blow through the jet; remove the float, and see if any water or dirt is present at the bottom of the float chamber; if so, drain it out.

A piece of copper tubing fitted too tightly into an india-rubber connecting pipe may fray the rubber, and so cause the pipe to become choked.

When starting the engine by hand, it is often necessary to flood the carburetter, so as to ensure petrol coming into contact with the air going to the cylinders past the top of the jet; or else to squirt some petrol through the compression

cocks into the cylinders before starting. This latter is termed "priming the cylinders."

In cold weather less air is required, since the increased density of the air allows a greater weight to pass through the air inlet. Failure to close the extra air inlet before trying to start will very often prevent the engine from starting. When starting up with a cold carburetter in cold weather, the petrol will tend to condense in the induction pipe; a rag wrapped round the inlet pipe will be of assistance in getting the engine under way.

The needle valve in the float chamber may be worn so that the float has to be raised above its normal level before it allows the needle valve to drop and shut off the petrol supply. The needle valve itself may also leak, due to wear, or dirt lying on its seating. Both of these will give too high a level of petrol in the float chamber and thus in the jet; hence the mixture will become too rich in petrol. If excessive, the carburetter float chamber will overflow.

The float may be leaky, and hence become too heavy; this, if only a small amount of petrol has leaked into it, will produce the same results as above. If much has entered, the float will not shut the needle valve at all, and the carburetter will therefore flood badly and overflow. For this reason, in engines where a flame is highly dangerous, the overflow and all drains should be led to a funnel well away from the carburetter so that a "backfire," or "flashback," will not cause a conflagration.

Flooding of the carburetter may also be caused by the upper part of the needle valve being too neat a fit in its guide, or by the needle valve being too light for its work, and so unable to shut on its seating against the head of petrol.

A piece of waste left in the air inlet pipe after an overhaul is by no means an unknown cause of failure of an engine to start.

(2) *Compression.*—If the engine is turned by hand and the compression cocks at the top of the cylinders are opened, during the compression stroke air will be forced out of these cocks at high speed, if the degree of compression is anything like good. It should be noted that small leaks in the inlet and exhaust valves, sparking plug terminals, &c., will not appreciably effect compression when actually running, owing to the very small fraction of a second occupied by the compression stroke, though, when tested by "hand revolution," the effect may be very marked, especially in large cylinders. The power required to turn the engine round by hand will also indicate roughly the compression in the different cylinders.

Should the compression be bad, examine for the following faults:—

(*a*) *Leaky or broken piston rings.*—The piston spring rings should bear against the side of the cylinder over their whole circumference. When testing for this, the cylinder walls should be covered with a thin coat of rouge, or red lead, and the piston spring rings put inside and moved up and down. The marking on the rings will indicate whether they are bedding properly and also if there is insufficient spring left in the rings. When fitting new rings allow $\frac{1}{32}$ to $\frac{1}{16}$ in. space between the butts of these rings (when in the cylinder) to allow for expansion.

The rings may be gummed into their slots in the piston by foul oil. Paraffin injected into the cylinder and left for a few minutes will dissolve the oil and release the rings.

(*b*) *Leaky valves.*—The valve and valve seatings may be pitted or worn. The seating on the cylinder and the bevelled edge on the valve should be ground together with emery powder, coarse powder being used to start with and the very finest when finishing.

If a groove has been cut on the valve during the process of grinding in, skim the valve up in a lathe and then finish off by grinding into place with very fine emery powder.

The valve, or its seating, may be warped as a result of overheating; if only slightly, grind in as above; if very bad, new valves will have to be fitted from spares, and the seatings reseated.

The valve spindles may be too tight a fit in their guides, due to too big a valve stem, or the presence of oil and carbon in the valve guide. Paraffin will clean the latter. If the valve stem is at fault, a rub with emery cloth will often give sufficient slackness.

Insufficient or no clearance may have been left between the end of the valve stem and the tappet. This is easily adjusted once discovered.

The timing of the cam shaft may be wrong. This must be checked. When checking, take all settings with the engine moving in the ahead direction only. (*See* special para. on valve settings, page 46.)

(*c*) *Ignition.*—Failure of the electrical arrangements may be due to:—

(i) The accumulator and coil ignition (if fitted);
(ii) The magneto ignition;
(iii) The sparking plugs.

If dual ignition is fitted, try each in turn. One of the two will probably be found correct and the fault thus partly

located. Should both fail, remove the sparking plugs and clean them with petrol, replace and try again.

When testing the two ignitions, the sparking plugs can be short-circuited to the cylinders by means of any steel tool having a wooden handle to hold it by, *e.g.*, a screwdriver. If a spark be observed between the end of the screwdriver and the cylinder it will show that the high tension current is, at any rate, reaching this point, and the length of this spark will denote its intensity. This indicates that the ignition is producing a spark, and hence the fault must be in either (A) the plug itself, or (B) in the timing of the magneto, or in its electrical connections, or in the accumulators (if fitted).

The test for (A) faulty plugs: The plug should be removed and tested by passing a high tension current through it in air under about 100 lbs. pressure per square inch. If a good spark passes across the plug terminals, and no signs of "flashing" occur elsewhere in the plug, it may be assumed to be in working order. It is no use testing the plug electrically under atmospheric pressure, as the resistance of the spark-gap under pressure is so much greater than under atmospheric conditions that a flaw in the insulation, which may have sufficient resistance to prevent a short circuit occurring under these latter conditions, will break down under the moderate pressures obtained when actually working.

To test for (B) timing, magneto and distributor: If the fault is elsewhere than in the plugs, test the timing of the ignition as follows:—

Turn the engine by hand slowly and note the timing of the spark in the different cylinders. This may be done,

with accumulators, by removing the plugs and turning the engine. When a spark is first seen to occur on any one plug, note the position of the crank arm, and see that the inlet and exhaust valves are shut for that cylinder. If they are not, but the crank is at the correct angle for ignition to occur, it will show that the distributor is one crank revolution out of time (*i.e.*, one-half cycle). In the case of magneto ignition, turn by hand as before, and observe the crank angle (and inlet and exhaust valves) at the instant when the two sides of the contact breaker come apart. This indicates that a spark will occur at this point in the cycle. If this is correct, the various ignition leads should then be traced most carefully, to make sure that they are connected up to the right cylinders and securely fastened to their respective terminals. If no spark appears while testing the terminal of the sparking plug by short-circuiting, examine all the electrical connections and see that none of them have come adrift or have been connected up to the wrong terminals.

A common cause of the magneto refusing to work is a short circuit to "earth" on the switch connection. This prevents the primary current being broken by the contact breaker and, consequently, the production of a spark.

The platinum points on the make-and-break may want adjusting, or the coils, condenser, or wire leads in the armature may have become short-circuited.

4. *Defects which may occur when certain specific conditions are observed.* (i) *A fouled plug.*—To find out which cylinder it is, slow down the engine by throttling as much as possible, and then short-circuit each plug in turn to the cylinder. When one of the non-faulty plugs is thus shorted, the engine

will slow down considerably, but when the foul or shorted plug is treated in this manner no difference is detected in the running of the engine. The temperature of the cylinders will often indicate the defective plug. Renew the plug with a new one.

(ii) *Faulty distributor.*—Examine the carbon brush on the distributor and see that no oil has got to it. If there are signs of grease, clean it off with petrol, &c., before replacing. The carbon brush may have worn a groove round the distributor, and the metal strips leading to the plug terminals may have got masked by the insulation. The best remedy for this is to turn up the inside of the cylinder carrying the distributor segments in a lathe.

(iii) *Defective insulation on connecting wire to plug.*—If the wire carries a high tension current, a spark will probably be seen at the point where the insulation has given way Indications will be the same as in (i). Examine the insulations carefully, and replace wire, if necessary, by a new length. Should the flaw in the insulation be small, a repair can be made with indiarubber solution and sticky tape.

(iv) *Faulty condenser.*—This ought not to occur in magnetos where a safety gap is provided to prevent too high a voltage being generated in the secondary circuit. It is usually indicated by sparking at the platinum points of the contact breaker. Should the platinum points of the contact breaker be worn and pitted the same indications will be present, so that it is as well to examine these platinum points first of all, and then, if necessary, to file them square and smooth, afterwards adjusting them to the correct distance apart at break—0·4 mm. ($\frac{16}{1000}$ in.).

(v) *All cylinders firing irregularly.*—Should all the cylinders be firing irregularly on cell ignition, but correctly when switched on to the magneto, it will probably be found that the accumulator has run down. Test the accumulator with the voltmeter; it should show 4 volts between its terminals. If less than this be recorded, connect up to the spare cell usually carried. If the cell registers 4 volts, examine all the terminals and also the battery contact breaker. The platinum screws should touch when the rocking lever is not depressed by the lugs on the insulated disc. These screws should only be ·4 mms. (or $\frac{16}{1000}$ in.) apart when separated by the action of the lugs. If these adjustments are incorrect, correct them by means of the screw attachment to the platinum point. Should the contacts be uneven (but only then) they may be filed perfectly flat with a dead smooth file and then re-adjusted. The vulcanite bush in the fulcrum of the rocking lever should be looked at to ascertain whether it is working freely or stiffly. It sometimes jambs, owing to dampness swelling the fibre.

(vi) *Cylinders firing weakly on magneto circuit and strongly on cell.*—If all the cylinders fire weakly on the magneto circuit, but strongly on the cell ignition, examine the contact breaker and its adjustments in the same way as for cell contact breaker, described above.

(vii) *No spark obtainable with the magneto circuit.*—See that the wire from the long contact terminal, to which the switch circuit is connected, is not short-circuiting to the frame. The earthing brush at the back of the rocking lever of the magneto contact breaker may be oily, and so preventing the magneto secondary circuit from being completed.

(viii) *No sparking at any terminal with both ignitions.*—A terminal of the distributor circuit has probably come loose or the wire short-circuited. Examine both carefully. The switch contacts should also be examined in all these cases.

(ix) *The magneto refusing to stop producing secondary current when switched off.*—This is probably due to oil having got underneath the carbon brush on the short-circuiting terminal at the end of the long contact screw of the magneto contact breaker; remove the cover over this latter, and clean the end of the carbon brush and the face it bears on with petrol. Then replace.

(x) *Backfiring.*—This occurs when the charge explodes immediately it enters the cylinder through the open valves and backfires into the induction pipe, and so to the carburetter, which it is liable to set alight if there be any petrol in it.

Causes of backfiring:—

(*a*) The most common cause is through a very weak mixture being supplied to the cylinder. This may be due to the petrol supply cock being only partly open, or the strainer or jet becoming choked by grit, dirt, &c.

(*b*) Carbon deposits get formed on piston head and walls of the compression space if the mixture supplied be constantly too rich in petrol; this carbon cakes, and becomes heated to incandescence, and so ignites the incoming charge immediately on contact taking place.

(*c*) A leaky exhaust valve, a weak spring, or a sticky spindle on an exhaust valve would allow hot exhaust gas to be sucked in from the exhaust pipe during

the induction stroke, and mix with the incoming charge, which it raises to ignition temperature, causing a premature explosion.

(*d*) Water in the petrol will sometimes be the means of producing a backfire due to the same cause as (*a*).

(*e*) Electric ignition leads not being joined up correctly, or one of the high tension leads making electric contact with another, and causing a spark to occur a revolution too soon, *i.e.*, just as the fresh charge is entering the cylinder.

(x) *Missfiring.*—This is said to take place when the charge is drawn into the cylinder and compressed, but passes through the whole of the working stroke without any explosion taking place. In a multi-cylinder engine the unexploded charge as it leaves the cylinder and comes into contact with the hot exhaust gases may cause an explosion to occur in the silencer or exhaust pipe. Missfires are caused by :—

(*a*) The mixture containing too much or too little petrol, thus forming a non-explosive charge. Missfires due to this cause usually occur in all, or pairs of, cylinders; if the latter, the prime cause will probably be traced to a faulty designed induction pipe or badly adjusted carburetter. Heating the induction pipe or air supply to the carburetter may, however, overcome it.

(*b*) Poor compression due to causes already mentioned. Missfiring in this case occurs in one or more cylinders, independent of relative position with regard to the inlet pipe.

(c) The mixture containing a quantity of exhaust gas, and so being too weak. Cause—a leaky exhaust valve. The leaky exhaust valve would also prevent good compression, so that this really comes under the same heading as (b).

(d) Defective ignition. With modern high-tension magnetos, defective sparking plugs are the most common cause of missfire.

(xii) *Pre-ignition.*—This happens when the mixture is fired on the compression stroke (usually without the aid of the spark), thereby tending to make the engine run backwards. This may be caused by:—

(a) The ignition spark being advanced too much when starting. Explosion will occur before crank is over dead centre, making the engine run astern a few revolutions. This should always be very carefully guarded against when starting an engine by hand, as the wrench given to the starting handle when pre-ignition occurs is sufficient to sprain or even break the operator's wrist.

(b) A hot piston or cylinder, due to the spark being too far retarded, causing much of the heat of the explosion to pass into cylinder walls and piston head. This causes the fresh mixture to become overheated during compression and so to explode prematurely.

Pre-ignition, even if it does not actually force the engine round in the wrong direction, may cause very heavy "knocking" in the bearings, which will strain the engine and reduce its speed. If it be very excessive it may easily produce fracture of

some part of the mechanism, usually the crank shaft.

(c) Overheated piston, &c., due to too weak a mixture. This is not an uncommon result, in cold weather, of too economical a carburetter.

(xiii) *Smoky exhaust*.—A smoky exhaust may be caused by too rich a mixture or by over-lubricating; the excess of oil supplied to the piston and cylinder is sucked up the sides of the piston during the suction stroke, and partially burnt.

(xiv) *Overheated cylinders*.—Having the mixture too weak, *i.e.*, containing too much air, is by far the most common cause. Too much petrol will also overheat the cylinders, though to nowhere near the same extent as too little petrol. The ignition too far advanced or too far retarded is also a cause of the cylinders running hot.

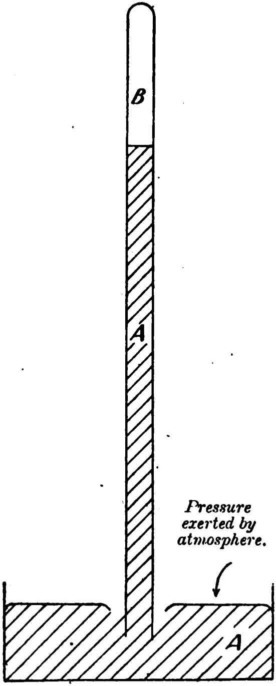
N.B.—The Gnome and Renault engines are dealt with in two separate manuals.

CHAPTER VI.—INSTRUMENTS.

1. *Mercurial barometer*.—The standard instrument for measuring the pressure of the atmosphere is the mercury barometer. In this instrument the pressure of the atmosphere is compared with the pressure at the base of a column of mercury of known height.

If an exhausted tube be placed with its open end in a cistern of mercury, the pressure of the atmosphere will force the mercury up the tube until the pressure at the level of the surface of mercury in the cistern, due to the column of mercury in the tube, is equal to that of the atmosphere acting downwards on the surface of the mercury in the cistern. The pressure of the atmosphere is conveniently given

in terms of the length of this column of mercury. (*See* fig. below.)



A Mercury *B Vacuum.*

An actual barometer consists essentially of the exhausted tube dipping into a cistern of mercury as detailed above. Alongside the glass tube is fixed a scale over which moves a vernier. The vernier is set exactly level with the top of the mercury.

As mercury rises in the exhausted tube the level of the mercury in the cistern will fall, so that, if the scale be fixed, its readings will no longer give the true distance between the surface of the mercury in the tube and of that in the cistern. To eliminate this error, one of two methods may be adopted. In the Fontin barometer the bottom of the cistern is made of washleather, and can be raised or lowered by means of a screw, until the surface of the mercury always just touches a fixed mark. In the Kew pattern barometer the length of the divisions of the scale on the tube is slightly altered, so that it always reads the correct height without adjusting the mercury in the cistern.

Errors and their corrections. (*a*) *Temperature.*—The first thing to be allowed for is the temperature of the barometer. If the temperature rises it affects the barometer in two ways:—

(1) The mercury expands, and therefore rises in the tube. This is equivalent to an apparent increase of pressure.

(2) The scale, against which the height of the mercury is measured, expands, causing an apparent decrease of the height of the mercury, or a fall of pressure.

To eliminate effects of change of temperature, the readings of the barometer are always corrected to what they would be if the whole barometer were at 32° Fahr. This correction

depends on the actual temperature at the time, the coefficient of expansion of mercury, and that of the scale.

(*b*) *Height.*—With a view to comparing the pressures at two or more stations, as, for example, in order to construct a daily weather map, allowance must be made for the different heights of the stations. The higher the station, the less will be the pressure. For purposes of comparison, therefore, the reading of the barometer is always corrected to what it would be if the station were at sea-level. The amount to be added is given by the formula :—

$$\log B - \log b = \frac{h}{60369} [1 + 0 \cdot 00204 (t - 32)],$$

where B is the pressure at the sea-level,

b the pressure at the station,

h the height of the station in feet above sea-level,

t the temperature of the air in degrees Fahr.

For convenience, tables giving this correction can be constructed, but a special table must be made for each station.

(*c*) *Index errors.*—The scale may not indicate the true distance from the surface of the mercury in the cistern.

(*d*) *Scale errors.*—The graduations of the scale may not be the right distance apart.

These two errors, (*c*) and (*d*), are best found by having the instrument tested against a standard barometer, and corrections must be applied to allow for them.

(*e*) *Imperfect vacuum.*—If a small quantity of air be left in the tube above the mercury it will cause the readings to be too low, the amount varying with the temperature and height of the barometer. This can easily be tested by

gently tilting the barometer until the mercury reaches the top of the tube. If it hits the top with a sharp click the vacuum may be considered good.

2. *Aneroids and barographs.*—The mercury barometer is the only really reliable instrument for measuring the atmospheric pressure accurately. It is, however, not a portable instrument, and for many purposes an aneroid is more convenient. This instrument contains one or more hollow flexible exhausted metal boxes. The pressure of the atmosphere on the outside is always tending to compress the sides of the boxes, while a spring placed inside tends to push the sides out. Hence, as the atmospheric pressure changes, the box will be expanded or compressed. By means of suitable levers the motion of the box causes a pointer to move over a graduated scale. This scale is generally graduated so that it gives pressures in terms of inches of mercury as measured on a mercurial barometer.

Errors.—It should be noticed that both the original setting of the instrument, as taken by the makers from the standard barometer, and the scale value depend on the adjustment of the instrument. The scale value, *i.e.*, the size of the graduations of the scale, is generally accurate, but the absolute value of the pressure in inches of mercury given by an aneroid can seldom be relied upon. This latter value will vary if either the scale or the pointer be permanently moved relatively to each other (*e.g.*, by altering the adjusting screw or moving the needle). When, therefore, the aneroid is used, it is for reading differences of pressure and NOT the absolute pressure at any given moment.

Aneroids are frequently subject, also, to errors due to changes of temperature. As the temperature rises the

elasticity of the spring inside the flexible boxes decreases, and the boxes are compressed more than they would otherwise be. This causes an apparent rise of pressure. Even many so-called "compensated" aneroids are subject to some error from this source.

Any form of barometer which gives a written record of the changes of pressure is known as a barograph. These are generally of the aneroid type. Instead of the motion of the aneroid boxes being communicated to a simple pointer moving over a scale, it is communicated to a pen moving over a chart wound round a revolving drum driven by clock-work. Otherwise the principle is the same.

Such barographs are subject to the usual errors of aneroids; and, in addition, errors may be introduced by excessive friction, either in the levers or between the pen and the paper. If, as the barometer rises or falls, the pen moves up or down in sudden steps there is almost certainly friction. Variation of pressure is almost always gradual. The friction may frequently be minimized by reducing the pressure of the pen on the paper; but sometimes the pivots of the bearings need adjustment. In this latter case the instrument should be sent to the makers.

Aneroids and barographs are frequently used to measure difference of heights. This is done by measuring the difference of atmospheric pressure at the two places to be compared. The difference of pressure is due to the difference of the weight of air above the levels of the two places. The actual difference of pressure corresponding to any difference of height is given by the formula on page 83. From this it is seen that the difference of pressure depends to some extent upon the temperature of the air and upon the mean pressure.

On aneroids and barographs which are provided with a scale showing heights, it is necessary, when fixing this scale, to decide upon a mean pressure and temperature of the air. When the pressure and temperature of the air differ from the assumed mean, it is obvious that the height reading obtained will not be quite correct. This error may amount to about 4 per cent. on account of difference of temperature, and to about 4 per cent. on account of the difference from the mean pressure. Some aneroids, however, are now made in such a way that the errors due to the pressure being different from the mean are very greatly reduced.

3. *Anemometers.*—The anemometer in general use up to 10 or 15 years ago was that known as the Robinson anemometer. This instrument consists of four arms which are capable of turning about a vertical axis. Each arm carries a hemispherical cup at its end. In consequence of the wind having more force on the concave side of the cups than on the convex side, these cups are driven round with a speed which is proportional to the velocity of the wind. A counting-gear is attached to show the number of times the cups have turned round. This instrument will only give satisfactorily the mean wind over a given time. For most aviation purposes the gustiness of the wind is, perhaps, the more important matter. The Robinson anemometer gives no indication of this, and is, therefore, of little use for aeronautical purposes.

A much more useful instrument is that designed by Dines. In this anemometer, a wind vane is mounted so as to turn freely round with the wind. The front part of the vane is in the form of a tube, the opening of which is always kept facing the wind. The hollow vane is connected through

an airtight joint to a pipe leading to the recording apparatus below. The wind blowing down the vane increases the pressure inside this tube. A second pipe led from the recording apparatus opens just below the vane in a series of small holes symmetrically arranged round a vertical tube. As the wind blows past these holes it produces a small suction.

The two tubes are connected to some form of pressure-gauge, which indicates the velocity of the wind. The gauge in the self-recording instruments consists of a vessel floating in water. The inside of the float is connected to the pressure tube from the vane, and the space between the outside of the float and the containing vessel is connected to the suction tube. The principle is the same as that of a gasometer, assuming that the latter were enclosed in a case. As the difference of pressure between the air in the two pipes increases, the float is raised out of the water. A pen attached to the float records the velocity at each instant on a chart rolled round a drum driven by clockwork. The pressure produced by the wind is proportional to the square of the velocity, so that the float must be made of a special shape if its movements are to be proportional to the square root of the pressure, *i.e.*, equal to the velocity and NOT to the pressure, which would be the case if the float were cylindrical.

This instrument requires very little attention. In setting up, its indications should be compared with some form of pressure-gauge, to see that the readings are correct.

The density of the water varies with temperature, and this causes the zero of the instrument to change. To correct this, the float is weighted with a few shot, so that the zero is always correct. It is also important to see that the level of the water is kept constant at the fixed mark (the float being in the zero position when this is tested).

The pressure produced by the wind is proportional to the density of the air. Any cause which makes the density of the air change will therefore alter the indicated velocity. The density of the air is changed by variations of temperature and pressure. But the changes produced at the earth's surface from these causes are too small to be important for matters connected with aviation. When, however, instruments on the same principle, *e.g.*, Pitot tubes, are taken up in aeroplanes to show the velocity of travel through the air, the change produced in the readings by the decrease of pressure, and therefore of the density of the air, may be appreciable. Thus at 5,000 feet the indicated speed will be 7 per cent. below the true speed.

In addition to recording the velocity of the wind, the Dines instrument may also be fitted to show the direction. In this case a rather larger vane is provided than is usual with the smaller instrument, mounted on ball bearings. The vane is connected to a rod which passes vertically down to the recording apparatus. This consists of a drum with two spirals, which engage two arms connected to the recording pens. As the vane turns round, the drum is also turned and moves the pens on the paper.

This type of anemometer is generally designed so that it records both the velocity and direction of the wind on the same chart.

4. *Erection of aeroplane instrument boards. Position of the instrument board.*—The instrument board should be fitted in the most convenient position, preferably directly in front of the pilot, and as high up as convenient. The board must be fixed in an upright position with its back vertical when the machine is in the position of normal horizontal flight. No

rubber insulation is necessary, as the instruments are made sufficiently strong to withstand vibration.

It has been found that the most accurate reading is obtained when, in a biplane, the Pitot tube is fitted on top of the top plane above one of the forward outside end struts. In a monoplane it is necessary to fit it to the leading edge of the wing as far away as possible from disturbance due to the propeller. The Pitot tube should point straight forward. When fitted to a biplane strut it should point horizontally, and when fitted to a monoplane's leading edge it should point slightly downwards (*i.e.*, 3° or 4°). These positions refer to the position of the machine when in normal horizontal flight.

Erection of board.—Before the erection of an aeroplane instrument board is commenced care should be taken to ensure that the following instruments are in order :—

Clinometer.—The board should be tilted backwards and forwards to ascertain whether the liquid is free from air bubbles. If any bubbles are found, tilt the board back until the liquid disappears from the indicating tube. Let the board then remain in this postion for a few minutes, after which the liquid should be found clear of air bubbles.

Air-speed indicator (*Pitot tube*).—Attach a small piece of rubber tube to the lower nipple on the side of the board, and blow very gently—preferably with the mouth away from the tube. The coloured liquid should now rise in the glass indicating tube. If any air bubbles are found in the liquid, they can be cleared by gently sucking the liquid below the zero mark. If after the liquid is quite clear of bubbles the reading is below zero, it will be necessary to add fresh liquid in the following manner :—

Take off the back cover plate of the instrument board, so that the rubber tubing from the nipples to the air-speed

indicator is exposed. Detach the rubber tube which leads from the upper nipple to the centre inlet at the top of the indicator, and pour through this opening a small quantity of distilled water, or preferably the special liquid supplied with the board. A slight suction should now be applied to the pressure inlet (*i.e.*, through the nipple at the bottom of the board) until the liquids are mixed. Sufficient liquid should be added to bring the liquid to the zero mark in the gauge. The rubber tube may now be replaced, and the board is ready for fixing to the machine.

The copper pipe leading from the pressure and static sides of the Pitot tube should be carried along the leading edge of the wing. At the lowest bend of the pipework it is advisable to fit a rubber joint, so as to be able to drain out any water that may get into the pipe.

The connection between the copper pipes and the instrument board should be made with rubber tubing. If any damping is required in the air speed indicator, this may be done with small bore glass tubing inserted between the copper pipes and the instrument board.

Before finally connecting up to the instrument board, it is advisable to make sure that the copper pipes are clear. To do so, it is better to suck through the pipes rather than blow through. Care should be taken to prevent any leaks in the pipes.

To test for leaks in the pressure pipe, get someone to hold a finger on the end of the Pitot tube. Then suck through the other end of the pipe and hold the tongue on the end of the pipe for a few seconds. If the pipe is air-tight, a slight hiss will be heard when the tongue is removed, owing to the partial vacuum in the pipe.

On no account must the Pitot tube be blown through with the indicator coupled to the pipes, unless the mouth is held away from the tube; even then care must be exercised to prevent excess pressure being applied.

If the pipes are quite clear, the indicator may be finally connected up, the pressure side of the Pitot tube being connected to the lower nipple on the instrument board. The air-speed indicator should now require no further attention.

If, at any time, it is found that the liquid does not return to zero, it is generally due to water having got into the copper pipes. Rain entering the Pitot tubes should be collected in the syphon—this can be emptied by taking out the screw below the syphon on the Pitot tube. To clear the pipes of any water, it is necessary to disconnect the instrument board and also the joint at the lowest point in the pipework, and blow through the pipes in both directions. Great care should be taken to get all the water out of the pipes, as the smallest drop will upset the reading.

If at any time the readings of the gauge are very low, it is most probably due to there being a leak in the copper pipes or in the rubber pipes inside the instrument board.

If there are no readings when the machine is in flight, it is probably due to a stoppage in the pipes or in the damping device.

Revolution counters.—Most of the revolution counters at present used in the Royal Flying Corps to indicate the number of revolutions given by an aeroplane engine are worked on the centrifugal principle. The action is very similar to that of the governor of an engine. Two weights are carried at the ends of arms which are hinged to

a central shaft. If the shaft be revolved the weights are also carried round with it, and the centrifugal force then excited in them causes them to fly outwards. Springs are arranged to press the weights inwards towards the shaft. Hence, if the shaft be revolved at any definite rate, the weights will take up a position depending on the centrifugal force pushing them outwards and the spring pressing them inwards. A system of levers is arranged so that, as the weights move outwards under the centrifugal force, a pointer moves over a scale graduated to show the speed of the shaft in revolutions per minute.

The connection between the shaft of the revolution meter and the engine is made by a flexible cable, which consists of a specially flexible wire running in a flexible metal tube. Within the revolution counter is a gear of 4 to 1, which causes the pointer to show four times the speed of the flexible cable.

The flexible cable is usually connected to the pump shaft of a Gnome, and either to the pump shaft or to the crank shaft of a Renault. The revolution meter must always be arranged to show the number of revolutions of the engine, so that certain gears must be placed between the flexible cable and its connection to the engine. In the Gnome the pump shaft turns at 7/4 the speed of the engine, and since the flexible cable must turn at 1/4 the rate of the engine a gear of 7 to 1 (down) must be placed between the pump shaft and the cable.

In the Renault the pump shaft turns at 2/7 the speed of the crankshaft, so that a gear of 8 to 7 (down) must be used when the cable is connected to the pump shaft. When the cable is connected to the crank shaft it is only necessary to

use a gear of 1 to 4 (down) in order to make the revolution counter read correctly. It may be here mentioned that the most satisfactory arrangement is to run the revolution counter off the pump shaft.

The flexible shafts should be lead in easy curves and not around sharp angles.

CHAPTER VII.—COMPASSES.

1. *General description.*—The compass is constructed on the principle of suspending a magnet (or system of magnets fixed parallel to each other, and referred to as the "compass needles") in such a manner that, remaining horizontal, they are free to take up the direction in which the magnetism of the magnetic pole directs them. This direction is called the "magnetic meridian."

A circular, graduated card, called the "compass card," is fixed to the compass needles so that one diameter of the card, the opposite extremities of which are marked North and South respectively, is in the same line as the direction of the needles. The point marked North (distinguished by a *fleur-de-lis*, or other special mark) is placed over that end of the needles which always points to the Northward. The extremities of that diameter, which is at right angles to the North and South line, are marked East and West, East being to the right hand when the observer is facing to the Northward. The compass card is thus divided into four quarters of a circle, or quadrants, and the points thus obtained are called the "cardinal points."

In the centre of the compass card a small semicircular cap is fitted, slightly hollowed on its underneath side. This supports the card by resting on a sharp-pointed pivot made of very hard metal. Thus the card is suspended on an almost frictionless point and is free to maintain its direction when the aeroplane is turned.

The pivot itself is fixed to the centre of a hemispherical bowl, called the "compass bowl." This bowl is covered at the top by a glass plate to protect the card from the effects of damp.

On the bowl of the compass will be found a black mark, called the "lubber's point," and when mounting a compass in an aeroplane this point should be in the fore and aft line of the aeroplane and pointing directly ahead. Thus it follows that the lubber's point moves with every turning movement of the aeroplane, and to ascertain the direction of the aeroplane's head, the observer has only to notice what point on the compass card corresponds with the lubber's point. This point is called the "compass course," or direction in which the aeroplane is being steered. The compass course may also, as an alternative, be described as the angle made by the point of the compass coinciding with the lubber's point and the North point.

2. *Errors to which compasses are subject.*—The compass is unfortunately affected by errors.

The ones chiefly concerning aviation are (*a*) variation; (*b*) deviation; (*c*) air bubbles in the liquid.

(*a*) *Variation.*—A suspended magnet, or compass needle, does not point to the "true" or geographical North, but to a point known as the "magnetic" North pole. The difference between this direction and the direction of the

true North is called the "variation of the compass," or shortly the "variation."

The variation changes according to one's position on the earth's surface, and also annually; the latter is very gradual, but the former must never be ignored. Variation is measured in degrees to the East and West of true North at Greenwich; at the present time the compass needle points 15° to the West of true North at Greenwich, and as one goes East, it gradually decreases till, near St. Petersburg, there is no variation, and still further East it changes to Easterly. To the West of Greenwich the variation increases to about 30° and then decreases again.

In the British Isles the change is not great—from 14° West on the East coast to 20° West on the West coast of Ireland, and this is decreasing by about 8′ annually.

The actual variation can often be obtained from the Ordnance Survey maps. These maps are made out on the true North and South principle, so that a course taken off them would be a "true course," and the variation must be applied before a "magnetic course" is obtained.

(*b*) *Deviation.*—This is due to local attraction of steel and iron fittings in the immediate vicinity of the compass; it varies both in magnitude and direction for different positions of the aeroplane. It will therefore be readily understood that it is necessary to place a compass in an aeroplane in such a position as to be as far as possible free from these influences. This, however, is a difficult matter; but so long as the compass is not affected to a greater extent than about 5° the error can remain uncorrected, as for practical work it will be found difficult to steer an aeroplane accurately enough for this amount of error to seriously matter.

If, on the other hand, the error is considerably in excess of 5°, it should be the work of an expert to correct it, by means of magnets placed near the compass in such a manner as to counteract the local influence on the needle. Should a pilot be of opinion that his compass is considerably "out" on a certain course, his best method is to point the aeroplane at a distant object situated on, or near, that course, start up the engine and note the reading of the card, at the same time taking a bearing of the object by means of another compass (known to be free from local error) placed in line with the aeroplane and object, but at some distance away. By comparing the two bearings obtained, the pilot can at once ascertain the error, and if unable to correct it by magnets, he must remember to apply it to his magnetic course.

This method can be employed for all directions of the aeroplane, and a table made out showing the deviation for every 10° or 20°; but it is more satisfactory if the pilot can have his compass properly corrected when it is first fitted on the aeroplane, so that the only error he has to apply is variation.

(*c*) *Air bubbles in the liquid.*—An air bubble is a large factor in producing inaccuracy in a compass. If the bubble is sufficiently big the vibration will cause the liquid to froth and the card will become illegible. At the same time the friction caused by the bubble moving in the bowl will tend to deviate the card from the magnetic north. In some cases it will even cause the card to revolve completely round. The best method of getting rid of bubbles is as follows :—Turn the compass bowl on its side so that the filling hole is at the top. Remove the plug and fill the bowl by means of

a very fine pipette. During this operation care must be taken to ensure that the passage of the air out of the bowl is not hindered by the presence of drops of liquid in the plug hole. When the bowl is *completely full to the top of the plug hole* replace the plug. Where an expansion chamber is fitted the air can be expelled, after removing the plug, by contracting this chamber.

2. *Aeroplane compasses.*—There are two or three types of compasses specially constructed for aeroplane work. The best known, perhaps, are (*a*) the "Clift"; (*b*) the "Kelvin and White" ("Chetwynd's"); and (*c*) the Naval and Military Aeroplane Compass.

(*a*) *The Clift compass.*—This is a liquid compass; that is to say, the bowl containing the suspended card is full of a liquid—a mixture of pure distilled water and spirits of wine. The object of the liquid is to prevent the card from being easily disturbed by vibration, quick rolling or pitching, and also to keep it from being jumped off its pivot.

On the top of the card is placed an adjustable pointer, called the course pointer. Before starting it is set to the course required, by pressing upwards on the milled nut underneath the bowl and rotating the card until the pointer shews to the point required. The milled nut is then pulled down, and the card returns to its seating with the pointer firmly attached to it. To steer the course the pointer is kept opposite the lubber point.

The compass bowl is mounted on jimbals from an aluminium frame, the jimbal ring being suspended by rubber washers. The compass thus always remains horizontal; and it might be mentioned here that this method of mounting,

has the advantage of being able to show at approximately what angle, both longitudinally and laterally, the aeroplane is flying, should a mist or cloud envelop the machine, and if no inclinometer is fitted to show this angle.

The compass card is marked in 10° intervals by a black triangle and at the intermediate 5° by a thin line. The four cardinal points are marked N., S., E., W. The degrees run from 0 at North, through 9 at East, 18 at South and 27 at West, the last figure 0 being omitted in each case, on account of space. Thus, 9 indicates 90°, &c.

(*b*) *The "Kelvin and White" Compass.*—This is also a liquid compass. The bowl is mounted in a box fitted with horse-hair to reduce the effects of vibration, and it is not suspended from jimbals, it being assumed that the suspended card has sufficient freedom to take up a horizontal position without coming in contact with the glass top.

The card is marked on the same principle as that of the "Clift," but, in addition, round the centre of the card are marked the points of the compass. These are of great assistance in steering an approximate course when the 10° markings cannot be distinctly seen.

(*c*) *The Naval and Military Aeroplane Compass.*—In this compass the bowl rests in its outer casing on a horsehair pad, and is kept in place by three trunnions with rubber rings, which fit into brackets on the inside of the case.

The bowl is filled with a mixture of three parts distilled water to one part alcohol. The bowl is filled through a filling plug (fitted with a brass screw) situated on its side.

The suspension of the compass card is arranged as follows:—

In the centre of the card there is a circular cap, inside which is fixed an amethyst. This amethyst rests on a pivot,

fixed to the bottom of the bowl and having an iridium pointed tip.

Attached to the underside of the card and $\frac{9}{32}$ inch from it there are two magnets, $2\frac{3}{8}$ inches long by $\frac{3}{32}$ inch diameter. The centres of the magnets are $1\frac{3}{8}$ inches apart.

The compass card is graduated from 0° at north every 10° right-handed through E. 90°, S. 180° and W. 270°. The final 0° of each number is, however, omitted, so that 280° reads 28°, &c., on the card. The card is also marked in cardinal and half cardinal points; the figures and letters in the north quadrants are red and in the south blue. On the outer rim of the card is marked a set of degrees inverted, which are reflected correctly in a prism fitted immediately over the lubber's point. The bracket for this prism is fixed to the bowl, but the prism itself can be moved to suit the individual user and his vision relative to the compass.

The lubber's point is of brass wire in the shape of a right-angled triangle, only two sides of which are seen, one when viewed directly and the other when the prism is used.

On the outer rim of the bowl is a movable circumference having a wire diameter across the top of the bowl. This is useful as a course-finder, and to assist the reflection of the lubber's point when the former is laid coincidental with it.

Let into the bottom of the bowl immediately under the lubber's point and prism is a $\frac{1}{2}$-inch diameter circle of opaque glass. Inside a holder which can be placed on various quadrants of the case is a dry cell—1·3 volts, ·3 amperes—which lights a ·5 candle-power clear bulb lamp fixed inside the case and under the bowl. The light from this lamp shines through the opaque glass and up into the prism. The lubber's point, and also the degrees on the card reflected in

the prism are thus illuminated so that the compass can be used at night.

At the bottom of the bowl, covered by a light plate held in place by four nuts, is an expansion chamber. This allows for the liquid becoming heated by the lamp, or by differences in the atmospheric temperature. This chamber can also be used for getting rid of a bubble in the liquid.

CHAPTER VIII.—INSTRUCTION IN FLYING.

The precise methods to be adopted in instructing, and the time devoted to each detail, will vary with the circumstances of each case, depending on the type of aeroplane in use and the aptitude displayed by the pupil. Whatever the aeroplane, or whoever the pupil, the general principles of instruction, will, however, remain the same.

The preliminary instruction takes place inside the shed: The pupil is placed in the pilot's seat, and the methods of controlling the aeroplane and engine are explained to him. A rough idea as to why the various movements produce certain results is also given. The pupil then spends some time practising the movements, more especially trying to use his feet, hands and head at the same time. This part of the instruction should be discontinued when the pupil is quite familiarized with his surroundings and has a good grasp of what he will have to do in the air. If this instruction is unduly prolonged, bad habits may be formed, such as holding the control lever to one side.

Instruction in the air is now commenced. This should only take place in calm weather, as the pupil would become confused if a sudden gust or remous necessitated an abnormal use of the controls. Assuming the aeroplane to be fitted with dual controls, two or three flights, amounting in the total to about three-quarters of an hour, at a height of about 150 or 200 ft., should be sufficient to enable the pupil to control the machine in calm weather clear of the ground.

The next stage of the instruction is the most difficult portion, *i.e.*, teaching the landing. During the first few landings the pupil merely looks on and follows the motions of the instructor. After this he should be allowed to place his hands and feet on the controls. The instructor gradually allows him to control the machine more and more, until finally, possibly without being himself aware of the fact, the pupil carries out the whole operation unaided. This practice is carried on for some time, until the pupil makes the landing with complete confidence. The practice landings should be made at rather greater speed than the minimum flying speed of the machine, so that, when the pupil tries to reproduce this speed when alone, a slight error on either side will not be of much importance. It is, however, perhaps of value to occasionally do a slow speed landing (warning the pupil of the fact beforehand), so that, should he find himself in such a position that a slow speed landing is essential, he will have some idea of the extent to which the angle of incidence must be increased with a view to obtaining the right speed

If there is no engine dual control, the pupil must next roll the machine on the ground for a few hundred yards, in order to get used to being alone in the machine and also to practice controlling the engine. Excessive rolling practice is not good. The pupil becomes accustomed to driving

the machine while it is in an attitude which would probably be dangerous in the air. He may also lose his respect for the control levers, coarse movements of which produce little effect on the ground, but mean bad flying, and possible disaster in the air.

After the "rolling," the pupil proceeds to carry out straight flights exactly as he did with the instructor. Two or three such straights should suffice. He is then allowed to make two or three circuits, including both right and left hand turns. After this the instructor should take the pupil again and show him how to land without his engine from small heights.

All the flying instruction up to this point should have been carried out at a distance from the sheds or other obstructions; but now the pupil may be allowed to start from and return to the sheds in the ordinary way.

During the instruction, the journeys to and from the sheds may be utilized to demonstrate the *vol plané,* and perhaps one or two fairly sharp turns may be done. A sharp turn is seldom necessary, but the pupil should be shown what it is like, in case he ever finds himself in such a position that it is necessary. There is the additional advantage that, when he comes to fly in something of a wind, he will have much more confidence in bringing the machine back from smaller angles than he has on previous occasions seen it brought back successfully.

It will be found that the mere taking of the Royal Aero Club certificate will instil great confidence in the pupil. At this stage any tendencies towards over-confidence should be at once checked.

After some further practice on the machine on which he has learnt, the pupil may be taught to fly a different type. One type or the other should now be selected, and the pupil

should use no other until he has thoroughly mastered this one. Constant practice in flying is necessary, for in aviation, as in seamanship, good results can only be obtained after long experience.

The pupil must be warned that, under no ordinary circumstances, should any machine be brought down steeply with the engine "full out," for not only is the machine subjected to excessive stresses, but the controls may get so stiff that difficulty may be found in actuating them. Conversely, if the controls feel "sloppy," it is a sign that the speed is too slow, in which case the machine should be dipped for a few seconds with the engine running.

Notes on various types of machines. Maurice Farman.—This machine is peculiar in being almost the only modern machine to retain the front elevator (in types up to 1914).

The Maurice Farman has a very good gliding angle, but not quite so good as is commonly supposed, for the reason that normally it carries its tail rather low, so that, during the glide, the machine may in reality be descending comparatively steeply, although the tail does not seem to be very high.

Many aeroplanes behave best in gusty weather, when a high speed is maintained; the Maurice Farman, however, is found to be most controllable at a speed of something less than its normal flying speed. Should bad gusts be met with at a certain altitude, and it is desired to come lower, the engine should be well throttled down on dipping.

Henry Farman.—The Henry Farman bears little resemblance to the Maurice Farman, except in details of construction and that the engine is behind the pilot.

In the air it is very quick in its movements. Whereas the Maurice Farman may be said to wallow when in a wind, the

Henry Farman jumps about lightly. It is possessed of a considerable amount of natural stability, and, at the same time, the controls are powerful. It has more head resistance than most monoplanes or tractor biplanes, and so loses its speed quicker when the engine is cut off to land; also, the lifting tail plane has a slight tendency to drop when the slip stream from the propeller is removed. The elevator, however, is powerful, and this tendency is easily overcome. A good pilot can land it at a very slow speed, though not quite so slow as the Maurice Farman.

The passenger seat is a little in front of the centre of gravity, and a slight difference is noticed when a passenger is carried—the machine is better balanced.

A beginner should be warned not to make a sharp turn on this machine until he has had some practice, because the main planes are behind him and the bank may become excessive before he notices it.

The pilot and passenger obtain a better view of the country than in any other type.

The Avro.—The Avro is a pleasant machine to fly. Only the outer part of the wing is warped, and thus the machine can be kept in good balance by adjusting the inner cells. The landing chassis is a very good design, and, while capable of standing very heavy shocks, does not bounce the machine up in the air if a slight pancake be made. The fore and aft control is sensitive, and the gliding angle very good. The rudder is also powerful, and banks the machine to a proper angle for turning, and, on this account, is useful also to help the lateral controls.

The B.E.—Is a tractor machine possessing a good range of speed, 70 to 40 m.p.h. It is capable of climbing, fully loaded, at a rate of 500 feet a minute.

The warping is controlled by lever, the steering by foot bar The wings are flexible throughout and the whole of each wing warps.

The fore and aft control is light, but the lateral control is inclined to be heavy and apt to tire the pilot during a long flight in bad weather.

The flying angle of the planes is 3°, but with the warp they have a maximum angle of 10°.

The greatest efficiency is obtained at 4° or 5°, but the machine is flown at the smaller angle of 3°, so that a large surface is available for getting a big range of speed and rapid climbing.

By reducing the angle of incidence towards the ends of the planes the self-warping effect is reduced and the pilot has to do more side control. The self-warping effect is most marked when the planes have the same angle of incidence throughout, but the machine is not so comfortable to fly.

Monoplanes.—Monoplanes generally are similar to handle to tractor biplanes. Though the maximum speed in both cases may be the same, the monoplane, having a smaller surface, cannot be landed so slowly, which is a great disadvantage. As a rule head resistance is cut down to a minimum, which is also a disadvantage when diving over obstacles to land in a confined space, since the speed becomes excessive.

A high-powered biplane can fly as fast as any practical monoplane, and has the enormous advantage of being able to go much slower. Of course a high-powered monoplane can be constructed to fly faster than a biplane, but it cannot be used except in very open country.

The monoplane is more pleasant to fly, principally because the controls are lighter to the touch, and because of the absence of the feeling of being shut in.

CHAPTER IX.—NAVIGATION OF THE AIR BY DAY.

1. *General remarks.*—Accurate navigation is obtained by the intelligent use of a compass, combined with a good knowledge of topography to assist in rapidly locating the position.

Great difficulty is experienced by pilots in finding their way across country at the first attempt, even if the locality is well known from below. The country presents a very different aspect when viewed from above, and only by constant practice can a pilot become what is known as a good cross country flier.

The secret of success in navigating an aeroplane is careful attention to details. The pilot's task is made considerably easier if he has a trained observer as passenger, with suitable means of communicating with the latter.

2. *Maps.*—Pilots must be well acquainted with map-reading. No map on a larger scale than 2 miles to an inch should be used for long flights; it is often impossible to use a larger scale than 4 miles to an inch.

It will sometimes be necessary in war to use foreign maps, the scale of which is usually given as a representative fraction. Pilots, when supplied with these maps, should immediately construct the corresponding English scale, *i.e.*, so many miles to an inch. This will facilitate rapid calculation of distances in units pilots are accustomed to work with.

The pilot, having been directed to proceed to a certain point, or number of points, must closely study his map to ascertain what guides he can best use to assist his navigation. If there is no side wind, and his compass is correct, a straight course from point to point is the quickest. The points on the map should be joined by a line, and the "true"

course measured. To this the variation (at Greenwich—15° W.) must be applied, and he then has the compass, or magnetic course to be steered. The latter should be written down and kept in some conspicuous position in front of the pilot. The distances from the starting point should also be marked, either at 10-mile intervals, or from some well-defined object passed *en route* to the next. It should be noted whether any very high ground is to be passed over necessitating a greater height being maintained at that point.

3. *Selection of objects, &c., as guides.*—The following remarks are the result of practical experience :—

(*a*) *Towns.*—Towns are obviously of the greatest assistance. No aeroplane should, however, pass directly over them, as not only is such a practice contrary to law, but also, unless at over 2,000 ft., the effects of any large works with blast furnaces, &c., will most certainly be felt. Towns should be clearly indicated on the map, either by underlining the name or by putting circles round them, so as to immediately catch the eye.

(*b*) *Railways.*—Railways are of very great assistance, and can be used to a large extent as a guide from point to point.

The conventional sign for a railway is a plain black line on the map, and no distinction is made between a line with perhaps four pairs of rails or one pair of rails. Thus it is quite easy to make a mistake, if a single line branches off from the main line in perhaps a not too conspicuous place. Branch lines to quarries, &c., are not often marked on the map, even though they may run a mile or more away from the main line. Tunnels, bridges and cuttings are marked on maps, and these will often be of assistance in picking up the correct line.

In spite of the above few details, which are liable to cause an error, a pilot should use railways whenever possible. He will find that, in windy weather when a course is perhaps difficult to steer correctly, and it is hard to allow for drift, it will be well worth his while to keep in sight of a railway, even if it takes him a little longer way round.

In such a case he should draw a line in the rough general direction of the railway and mark off its magnetic course. By comparing this with his compass, it will not only act as an assurance that he is following the correct railway, but it will also assist him should he become enveloped in a cloud or mist for a short time.

(*c*) *Roads.*—As a general rule roads are not a particularly good guide. There are so many of them in England which twist about considerably. Main roads are often less noticeable from a height than the minor roads. The telegraph wires and poles (a sure sign of an important road) are also very hard to see.

There are, however, exceptions to the main road rule. Roman roads, being usually absolutely straight, can generally be picked out easily, and also roads over a moor or plain, where there are few others in their vicinity with which to confuse them.

(*d*) *Water.*—Water can be seen from a great distance, and is a good guide. But after much rain a pilot must take into consideration the possibilities of a flooded stream causing the surrounding meadows, &c., to be inundated to a depth of perhaps only a few inches, but nevertheless having an appearance of a good sized lake or broad river, which cannot be located on the map.

Rivers are very winding, and are often almost concealed by high trees on either bank. A pilot will usually waste time if he elects to follow a river as a means of getting from point to point. On most maps the smallest rivers are marked very distinctly, which will at first encourage a pilot to follow them.

(*e*) *High ground.*—From a height of 2,000 ft. and over the country presents quite a flat appearance, and contour cannot be recognized. Nevertheless, the pilot should not fail to mark on his map any high ground with steep contours, as a warning that the landing is likely to be difficult, and as a reminder to fly high at this point.

(*f*) *Forced landings.*—Landing ground is hard to recognize as being good from a greater height than 1,000 ft. As it is usual to fly at somewhere about double this height, the aeroplane can glide for some distance before a spot is finally selected.

The best time of the year for flying is undoubtedly the autumn, when the crops are in. At this time a pilot should choose for preference a stubble field, which, from a height, presents a lightish brown appearance. By doing this he can be quite certain that the surface will be smooth, without ditches or mounds, whereas the ordinary grass field as often as not abounds in the latter. Dark green fields are usually found to be roots, and as such should be avoided, if better ground is available. Should a pilot land in a field of young wheat, &c., he will do well to get the first batch of sightseers to remove his machine to a corner of the field; this will prevent more damage to the crops than he has already caused.

(*g*) *Wind.*—Navigation would be comparatively easy if wind did not enter into the question. It is the more difficult to allow for, as it varies both in strength and direction at various heights (*see* Appendix III).

A side wind will cause an aeroplane to drift, that is to say, it will have to head up into the wind to a greater or less extent in order to remain actually travelling along the course required.

Should such a side wind be blowing when a pilot is about to start on a flight to a point some distance away, it will be quite worth his while to make a small diagram calculation on his map to ascertain how much he should allow for it. This can be done in the following manner :—

A is the point of departure.
B is the point of destination.
Join AB (which should represent the magnetic course).

From A (point of departure) draw a line down wind (*i.e.*, with a S.W. wind the line would be N.E. from A). Estimate the speed of the wind (say, 20 m.p.h. at 2,000 ft.).

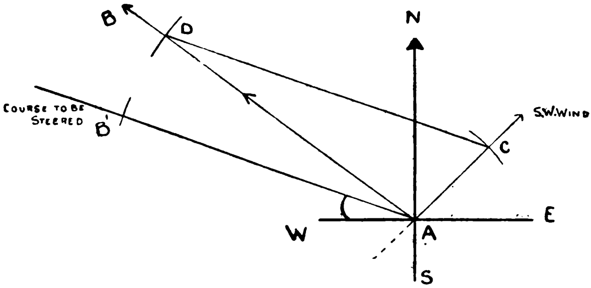
Speed of aeroplane 60 m.p.h. (say).

This gives a ratio of 1 to 3 (speed of wind to speed of aeroplane).

Lay off 1 in. along the wind line from A, cutting this line at C. With centre C and radius 3 in., describe an arc cutting AB at D ; join DC.

Then a line drawn parallel to DC through A will give the course that must be steered in order to reach B. The course in degrees can be found by measuring the angle BAW, and, in this case, adding to the angle thus formed 270°. Line AD will give the speed of the aeroplane relatively to the ground.

Thus :—



On starting off it is as well to circle while climbing, note the direction of the drift and pass directly over the point of departure. When directly over the point of departure, point the aeroplane on to her magnetic course and select some distant object on that course. Then head the machine up into the wind as necessary so as to pass over the object selected.

(*h*) *Time.*—The taking of times is often very much neglected, but nevertheless, it is an extremely important matter. In an aeroplane it is most difficult to estimate time. On calm days it seems to pass quickly, but on a rough journey the minutes pass very slowly; thus it often happens that a pilot who has not checked the time of passing some object expects to pass the next long before it is really due. From the commencement of a cross-country flight to the journey's end, the times at which the objects selected as guides are passed must therefore be checked.

(i) *Height.*—Over ordinary country, where there are no very high hills or mountains, a good height to keep at is from 1,500 to 2,000 ft. The presence of low-lying clouds, or of an unsteady wind, may necessitate a less or greater height, respectively, than those mentioned being kept. As a general rule, the speed and steadiness of the wind increase as higher altitudes are reached, so that in making a flight down wind it may be sometimes more advantageous to fly higher than would be the case if the flight were being made against the wind.

4. *Instruments.*—The following instruments should be fitted in an aeroplane intended for cross-country work :—

A properly adjusted compass.

A watch, preferably strapped to the pilot's arm. If fixed to the aeroplane without adequate means of preventing vibration, it will probably stop or not keep good time.

An aneroid with adjustable height reading.

An engine revolution indicator. However skilled a pilot may be in detecting faulty running of his engine, after a long flight his hearing will not be so good, and an indicator will assist him considerably.

A speed indicator, either in the form of a Pitot tube or a pressure plate instrument. This will indicate the speed of the machine through the air, and will be found invaluable when in a cloud, or when the ground is obscured from view by mist.

An inclinometer is required for ascertaining the angle of flight when the earth is not visible. For longitudinal angles the speed indicator is usually sufficient, as by noticing whether the speed is increasing or decreasing the pilot knows whether he is going "down" or "up."

A map board or case. For moderate distance flights, the pilot will find that a board placed in a conspicuous position will be quite sufficient to pin his map to; but for longer flights, he may find it necessary to cut his map into strips and use a roller map case. This method has the drawback that consecutive courses, though perhaps differing considerably, will have to be drawn as if in a straight line. It thus requires a little practice for a pilot to adapt himself to its use.

CHAPTER X.—METEOROLOGY.

1. *Introductory remarks.*—Although great advances have in late years been made in the knowledge of the conditions and changes taking place in the atmosphere, yet a very large number of questions of great interest from an aeronautical standpoint still remain unanswered.

Further, the changes taking place in the atmosphere are very complicated, so that the problem of forecasting weather, in detail, is a matter of the greatest difficulty.

Fortunately the wind, which is one of the most important factors to the aviator, is the most amenable to simple physical laws.

2. *Atmospheric pressure.*—The pressure of the air—which will be seen later to be a variable quantity, and its changes to be of great use in forecasting weather—is due to the weight of air above the place where the pressure is exerted. It will be readily seen that the longer the vertical

column of air, and the greater the density of the air, the greater also will be the pressure exerted at the bottom of the column. Hence at two places, one above the other, the pressure at the lower place will be equal to the pressure at the upper plus the pressure due to the weight of air between the two. This difference in pressure will not be constant, but will depend on the density of the air, which in turn varies with the temperature and pressure.

The difference of pressure at two places one above the other may be found as follows :—

Let B be the pressure at the lower place ;
Let b be the pressure at the upper place ;
Let h be the difference in height in feet ;
Let t be the mean temperature of the air between the places in degrees Fahrenheit ;

$$\text{Then } \log \mathrm{B} - \log b = \frac{h}{60369}(1 + {\cdot}00204\,[t - 32]).$$

Or the difference in height may be found from—

$$h = 60369\,(1 + {\cdot}00204\,[t - 32]) \log \frac{(\mathrm{B})}{(b)}.$$

The temperature of the air generally falls off with height, but near the surface of the ground the rate of decrease is often far from constant, and it is not uncommon to find a warmer layer above a colder one. The average rate of decrease is about 1° Fahr. for every 300 ft. Above 5,000 or 6,000 ft. the rate of decrease of temperature becomes nearly constant at 1° Fahr. for every 300 ft. At very great heights (over 30,000 ft.) the temperature ceases to fall with height, and may sometimes rise again. This region, however, is well above the height practicable for flying.

If readings of the atmospheric pressure, as measured by a barometer (*see* Chapter VI), are taken at the same time at a number of different places situated over a wide area, and are then plotted on a map against each station, the readings will be found to be arranged in some order. Certain areas will have low-pressure, and others will have high-pressure.

On any topographical map, lines or contours are drawn showing the heights of the ground. Equally, on the pressure map, it is possible to draw lines similar to contours, showing the heights of the barometer. As all places on any one contour are at the same height, so all places on any line on the pressure map will have the same atmospheric pressure. These lines are called "isobars."

The isobars are generally drawn for each tenth of an inch of mercury, *i.e.*, the difference of pressure between two places on two consecutive isobars will be one tenth of an inch of mercury. In regions where there is a large difference of pressure between places not far apart, the isobars will necessarily be close together, just as on a map, where the slope of the ground is steep, the contours will be close together.

The rate at which pressure changes from place to place, is known as the "pressure gradient." When the pressure is changing rapidly the gradient is said to be "steep."

3. *The wind and its connection with atmospheric pressure.*—When one part of the country is under high-pressure, and another under low-pressure, it might at first be supposed that air would be forced out from the region of high-pressure towards that of the lower pressure, and that winds would be found everywhere blowing straight outwards from the

high-pressures, and straight inwards towards the low-pressures. Reference to any weather chart will, however, show that this is not what happens. The winds blow in a direction which is more nearly parallel to the isobars than at right angles to them. The explanation of this phenomenon is to be found in two facts :—

(*a*) The earth is revolving about its axis. This causes all winds in the northern hemisphere to be deflected to the right of the path which they would follow if they were affected only by the pressure gradient, and tends to make them blow parallel to the isobars; similarly, winds in the southern hemisphere are deflected to the left of this path.

(*b*) Friction between the air and the surface of the ground tends to lessen the deflection of the winds caused by the rotation of the earth.

The result of these phenomena is that the winds at the surface blow round the centres of low-pressure in in-curving spirals in an anti-clockwise direction (in the northern hemisphere), and in out-curving spirals in a clockwise direction round the centre of high-pressure.

If it were possible to eliminate surface friction, the velocity of the wind could be calculated theoretically from the pressure gradient. An imaginary wind having this theoretical velocity and direction is called the "gradient wind," and its velocity and direction are known as the "gradient velocity" and the "gradient direction."

At a height of 1,000 to 2,000 ft. above the surface of the ground the effect of surface friction is very small, and the actual wind has very nearly the gradient velocity and direction.

The table given in Appendix I shows the gradient velocity for different values of the pressure gradient.

The strength of the wind is generally expressed in terms of its velocity in miles per hour. For some purposes it is more convenient to use a rougher classification, and to divide all winds from calm to a hurricane into 12 groups, denoting the strength of the wind by the number of the group into which it would fall. As this system is due to Admiral Beaufort, it is known as the "Beaufort scale." The strength of the wind may also be given in terms of the pressure exerted by it, say, on a flat plate. This pressure varies as the square of the velocity.

Appendix II gives the relation between the velocity in miles per hour, the Beaufort number, and the pressure exerted on a flat plate in lbs. per square foot.

4. *Gustiness of the wind.*—It is found that the velocity of the wind does not remain constant. It is continually changing, and as a result is always rather gusty. The gustiness varies with different places and with different directions of the wind. The difference between the average maximum velocity attained in the gusts and the average minimum velocity attained in the intermediate lulls is known as the "fluctuation" of the wind.

The ratio of the fluctuation to the mean velocity of the wind is called the "gustiness," and this is found to be roughly constant for any one direction at any place, whatever may be the mean velocity of the wind.

5. *Forecasting.*—From the foregoing it has been seen that when barometric pressures are plotted on a map they are arranged according to some order. It is now necessary to consider certain typical cases of pressure distribution.

The cyclone.—This type consists of a centre of low-pressure from which the pressure rises on all sides. The isobars are roughly circular about the centre of low-pressure. The winds blow in an anti-clockwise direction round the centre (clockwise in the southern hemisphere).

Different parts of a cyclone have each their own type of weather, of which the following description may be given :—

The temperature is always higher in front than in rear, the warm air in front having a peculiar close muggy character, quite independent of the actual height of the thermometer. The cold air in the rear, on the contrary, has a peculiarly exhilarating feeling, also quite independent of the thermometer.

The force of the wind depends almost entirely on the gradients. In the centre it is dead calm, and the steepest gradients are usually found at some distance from the centre.

The relative steepness of the gradients measures the ntensity of cyclones.

If two lines are drawn through the centre of the cyclone, one in the direction parallel to that of its motion and another at right angles to this direction, the cyclone will be divided into four quadrants, each of which has its peculiar type of weather. The line at right angles to the direction of motion is known as the line of " trough."

The broadest feature of the weather in an average cyclone consists of an area of rain near the centre surrounded by a ring of cloud, but both rain and cloud extend further to the front than to the rear of the centre. When, however, examining the nature of the cloud and rain as well as the general appearance of the sky, it is found that the cyclone

is divided into two well-marked halves by the line of the trough. The front may be further divided into right or south-east, and left or north-east fronts, which, though they have much in common, are sufficiently different to be classified separately. Coming now to more minute detail, in the left or north-east front, when the steepest gradients are somewhere south of the centre, the first symptoms of the approach of a cyclone are a halo, with a gradual darkening of the sky till it becomes quite overcast without any appearance of the formation of true cloud; or else light wisps, or barred stripes of cirrus moving sideways, appear in the blue sky, and gradually soften into a uniform black sky of a strato-cumulus type; nearer the centre, light ill-defined showers fall from a uniformly black sky, the wind from some point between south-east and north-east blows uneasily, and though the air is cold and chilly there is an oppressive feeling about it. These appearances continue till the barometer commences to rise, when the character of the weather at once begins to alter. In a cyclone, when the steepest gradients are somewhere to the north and east of the centre, the general character of the weather is the same as above described, but much more intense, the wind rising at times to a heavy gale, and the ill-defined showers developing into violent squalls.

In the right or south-east front, when the steepest gradients are to some point south of the centre, which are the commonest cases in this country, the first symptons are likewise a gradual darkening of the sky into the well-known pale or watery sky, with muggy oppressive air; or else, as in the north-east front, wisps of cirrus first appear in the blue sky, which gradually becomes heavier and softer till the sky is uniformly overcast with a strato-cumulus type of

cloud. Nearer the centre, rain, usually in the form of drizzle, sets in, and the wind from some point between south-east and south-west, varying in force according to the steepness of the gradients, drives the cloud and rain before it.

The line of trough marks the line of heavy showers of squalls, especially the portion on the southern side of the centre.

The general character of the west or near side is a cool, exhilarating feeling in the air, with a high, hard sky, of which the tendency is always to break into firm detached masses of cloud. The rain, which occurs near the centre, is usually in cold, hard, brisk showers or hard squalls, and the general look of the weather presents a marked contrast to the dirty appearance of the weather which characterizes the whole front part of a cyclone. Further from the centre, showers or squalls are replaced by simply detached masses of cloud, and finally these disappear, leaving a blue sky. The wind from some point between west and north blows gustily.

The whole of the rear of a cyclone partakes of this general character, but the change of weather along the north of a cyclone is not nearly so marked as along the southern portion.

The motion of cyclones is, as a rule, from west to east, the general direction being about west-south-west to east-north-east. Occasionally they move north or south, but seldom from east to west. They may also at times remain stationary for a day or two, but this is rare.

The anticyclone.—The distribution of pressure in an anticyclone is almost the reverse of that in a cyclone. It consists of a central area of high pressure, from which the pressure gradually decreases on all sides. The gradients

are generally very slight, so that the winds, which blow round the centre in a clockwise direction, are very light. Unlike a cyclone, no very definite description of the weather can be given—in fact, almost any type of weather may be found in an anticyclone, except strong winds; heavy rain is also infrequent. On the whole the weather is fine, but in winter periods of dull cloudy weather often accompany an anticyclone. On the other hand, days with cloudless skies, and keen frosty weather in winter or hot weather in summer, frequently occur in anticyclones. Unlike cyclones they have no general direction of motion, but move very slowly and in any direction. They frequently remain stationary for several days together. In the colder months, anticyclones are very frequently accompanied by fog.

Secondary depressions.—On the outside of a cyclone irregularities in the isobars frequently occur. These may be mere kinks in the isobars, or they may be well marked and have an independent area of low-pressure. A very common form is for the isobars to have approximately the shape of a "V," such cases being known as "V" depressions. The secondaries travel round the main depression in the same direction as do the winds, viz., anti-clockwise.

The weather in these secondaries varies according to whether they are well marked or not. Where only a small kink occurs, only cloudy skies and temporary rain may be produced; but if they are well marked, and the gradients are steep, the winds may become very strong and the weather very bad.

In a secondary depression of average intensity the sequence of weather is as follows:—

As the secondary approaches, the weather is similar to that in the right front of a cyclone; as the centre of the

secondary passes, the barometer suddenly begins to rise, and there is frequently a heavy squall, as in the trough of a cyclone, and the wind suddenly veers to a more northerly quarter.

On the side away from the centre of the main cyclone the winds are generally very strong, but between the secondary and the main depression they are light. In the rear of a secondary the weather is similar to that in the rear of a cyclone.

The wedge.—It frequently occurs that a series of cyclones pass across the country in a continuous succession. Between two of these cyclones the isobars will be roughly "V" shaped, but in this case with the highest pressure within the "V." These are times of brilliantly fine weather, cloudless skies, and clear atmosphere, but as another cyclone is approaching they last only a short time.

Line squalls.—It has been said that, as the trough of a cyclone passes, there is frequently a heavy squall. This is generally of the type known as a "line squall." Such a squall stretches in a line for a long distance across the country, and may be as much as 500 miles in length. The squall moves in a direction approximately at right angles to its length, with a velocity of between 30 and 50 miles per hour. The breadth of the squall is usually narrow, so that it does not last long—generally from half an hour to two hours. The squall gives no sign of its approach, except that if the sky is fairly cloudless a long line of well-marked cumulus may be seen in the distance gradually coming nearer. As the squall reaches the observer, the wind suddenly increases (or occasionally increases slightly and then suddenly decreases), and at the same time the direction suddenly changes to a more northerly quarter.

The barometer generally shows a small sudden rise, and the temperature always suddenly falls. Heavy rain, and frequently hail, with sometimes thunder, set in at once. The whole squall is of a violent nature, and may do considerable damage. This phenomenon seems to be caused by the sudden inrush of a cold current of air from some northerly quarter, which forces the warmer air in front of it to ascend. As these squalls give no warning of their approach, and as they are very violent, they are of a particularly dangerous nature. They are to be expected when the trough of a depression passes, and especially in a "V," or secondary. After one squall has passed, others frequently follow in the next few hours. These line squalls may also occur at times in conditions that would be expected to give only a moderate westerly or south-westerly wind. An observer can only forecast these phenomena with certainty when he is in possession of information that a squall has passed certain points and is travelling in his direction.

Fog.—True fog (clouds on the surface of the earth are not true fog) on land is only formed when there is little wind and when the sky is cloudless. During the day the air is warmed and takes up water vapour. On a calm cloudless evening the ground is cooled by outward radiation, and the air near the ground is also cooled. This cold air, being heavier, flows down the sides of hills and mixes with the warm moist air over the valleys, which is thereby cooled. The cooling so produced may be sufficient to cause some of the water vapour to condense, and fog is formed. If there is much wind the air is kept stirred up and no cold layer is formed. If, on the other hand, the sky is cloudy, the ground is not cooled by radiation, so that in this case no fog is formed.

Conditions of the atmosphere affecting aviation.—The available knowledge of the upper air is still rather small, but some information has been obtained which is of use to aviators.

If it is required to ascertain what the wind is at any height above the ground, there are several methods by which this information may be obtained.

First, by sending up a small balloon which drifts along with the velocity of the wind at the height it has reached. The balloon is observed by theodolites, and the velocity and direction of the wind at any height can be calculated accurately. This, however, is an elaborate method and takes considerable time.

Secondly, some information may be obtained by observing the motion of the clouds. From these, the direction of the wind at their level may be accurately gauged. It must, however, be remembered that the height of the clouds cannot definitely be fixed without suitable instruments, and therefore the velocity is only very approximate. Nevertheless a rough idea may be obtained by noting whether the clouds are moving quickly or slowly. The lower the clouds are the faster they " appear " to move.

Thirdly, an estimate of the upper wind may be obtained from a daily weather map, by calculating the gradient wind as explained in Appendix I. At a height of 1,000 ft. or more, the gradient wind is found to agree very well with the wind at these heights, as found by means of kites or pilot balloons.

Fourthly, it is possible to estimate the upper wind from the known surface wind at the time. It is nearly always found that for the first 1,000 or 2,000 ft. above the surface the velocity increases directly as the " height above sea-level." Hence, if, at a place 500 ft. above sea-level, the surface wind were 15 miles per hour, the velocity at 500 ft.

above the "surface" (*i.e.*, 1,000 ft. above sea-level) would be expected to be 30 miles per hour; and at 1,000 ft. above the surface (*i.e.*, 1,500 ft. above sea-level) 45 miles per hour. This regular increase in velocity goes on till the gradient velocity is reached, after which the wind generally remains almost constant, but may increase or decrease. In the case of easterly winds there is very frequently a decrease at higher altitudes. The direction of the wind a few thousand feet up is slightly changed in a clockwise direction from that of the surface wind, *i.e.*, if the surface wind were south the upper wind might be expected to be south-south-west, or south-west. A table of changes in velocity and direction, which are the results of observation, is given in Appendix III.

It is a well-known fact that the wind is frequently stronger in the day than at night. This is nearly always the case, except in rough weather. At sea the effect is not so marked. The decrease at night, however, only takes place at the surface. At a height of from 1,000 to 2,000 ft. the wind is stronger at night than in the day. The cause of the surface decrease in velocity at night seems to be the formation of a shallow layer of air on the ground, which does not take part in the general movement of the air.

While the velocity of the wind increases with height, the gustiness almost invariably falls off, so that the wind is more steady above than at the surface. No definite rule can be given about the relation of gustiness and height.

Allied with gusts are "remous" experienced in flying. These may be due to two causes: First, a horizontal gust suddenly striking the aeroplane, and causing a temporary change in its velocity through the air; this will produce a momentary change in the lift. Secondly, there may be an

ascending or descending current, which will make the aeroplane rise or fall.

These upward or downward currents may be caused either by trees, buildings, and the contour of the ground, or they may be due to rising currents of hot air.

Another possible occurrence is for the aeroplane to pass into a mass of air moving in a different direction to that in which it had been before. This would also cause a temporary change in the speed through the air, but this ast cause is not likely to be a common occurrence.

CHAPTER XI.—MOTOR TRANSPORT.

1. *Engines.*—In general motor car engines are governed by the same principles as those applicable to Aero engines. The general chapter on engines must, therefore, be read in conjunction with this chapter. In addition, the following points should be noted:—

(*a*) Bearings should normally be examined after 10,000 miles. They may only require to be tightened up, or they may be badly worn, thus necessitating remetalling. If, however, there is sufficient metal left the flat faces of the bearings may be touched up with a file.

(*b*) New piston rings will require to be fitted at this period.

(*c*) Whenever for any reason an engine is taken down it is advisable at the same time to grind in the valves, clean the pistons and cylinder heads, examine the gudgeon pins and their fittings, and clean all oil leads and filters. When reassembling the engine it is necessary to use new washers and packings throughout.

(*d*) As all motor cars are fitted with variable ignition care must be taken in tuning to allow sufficient "advance" and "retard" to be given on the ignition quadrant. In cases where independent magneto and accumulator ignition are fitted, each system must be adjusted so as to spark at the same point in the cycle.

2. *Routine examinations.*—Periodical inspections of the car or lorry must be made and the following points seen to:—

Every time the car is used.—

(*a*) Tyres correctly inflated and spare wheel in place, and tools for changing wheel or rims (jack and brace).

(*b*) Radiator and petrol tank full. Carry spare tin of petrol and strainer.

(*c*) Sufficient lubricating oil in the pump or reservoir, and that the feeds work freely.

(*d*) Accumulators properly charged and coil working.

(*e*) Brakes working properly.

Every day before duty.—

(*a*) All the above points.

(*b*) Oil holes on steering arms, knuckles, universal joint, &c., cleaned and oiled. This should be done after the car has been cleaned.

(c) Grease caps on springs and shackles screwed down and properly supplied with grease.

Weekly.—

(a) Sparking plugs and ignition looked over, magneto oiled and cleaned.
(b) Examine water joints, see pump packing does not leak, and also that the radiator is tight.
(c) Refill axle caps and examine clutch leather.
(d) Open gear box and see that there is sufficient grease.
(e) Change tyres about on wheels if uneven wear is noticed.
(f) Examine bodywork.

Monthly.—

Grind in valves (or after 1,000 miles running).

3. *Care of grease and oil caps.*—There are several parts on the car which require regular lubrication, and which are not supplied automatically. These parts are generally equipped either with grease cups or oil-holes. Particular note should be made of oilers on the spring hangers, universal joints, steering pivots, knuckles, steering gear-box and such like. It is also necessary, periodically, to introduce some lubricant between the laminations of springs.

Drivers of motor vehicles should make themselves thoroughly acquainted with all the grease and oil caps on their cars, and must systematically keep them properly supplied. The frequency of the application of oil or grease will depend on the amount of running.

4. *Care of clutch.*—The clutch may want a little attention. If a leather clutch is fitted, and the leather cone can be got at, it may be brushed over with at least one coat of castor-oil,

the latter being allowed to soak in. This should be done when the clutch is "fierce" owing to the leather becoming glazed and hard. It does not follow that a new clutch leather is necessary when a clutch is not giving satisfaction. Sometimes it will be found that a shoulder of about $\frac{1}{16}$-in. deep has worn on the old leather. This should be carefully trimmed off with a sharp file, which will give the leather a new life. This allows the cone to go further home, giving a closer contact between the surfaces.

A special detail to watch is to see that the copper rivets are well below the surface of the leather. If they become flush with the leather, the result would be a nasty gripping, or even difficulty in disengaging. A metal to metal clutch requires to be cleaned out occasionally with paraffin. A hole is generally provided for the purpose in the clutch casing. If the clutch is too fierce a little thin mineral oil will put it right.

5. *Gears.*—The gear-box should be regularly inspected to see that there is an ample supply of lubricant, but not an excess. It is quite unnecessary to fill up the cases, as this will only result in the gear grease flooding out at the joints and bearings and making them a receptacle for mud and dust. The amount of lubricant used should be sufficient to cover the lower teeth of the gears, the rest will look after itself. (*See* "Differential gears.")

6. *Differential gear and chains.*—The differential gear transmits the power from the speed-change-gear to the rear axle of the car. Cars which are made with chain drive to both wheels have the differential gear arranged on the countershaft at the ends of which the chain sprockets are fitted. Usually the differential and change-speed gear are fitted in the same case.

Chains require to be renewed occasionally and taken up as they wear. Clean with paraffin and lubricate with graphite on a brush. Links of various lengths can be added.

7. *Care of brakes.*—Attention to the brakes is very important. They should be adjusted as closely as is permissible, the jaws being set so as to just clear the drums but not to set up any permanent friction. A screw adjustment is provided for this purpose. Too much clearance lessens the responsiveness of the brakes, especially in an emergency. The rods actuating the brakes should be carefully examined from time to time for any signs of weakness. Particular attention should be paid to ensure that the jointing pins have split-pins properly fitted.

8. *Cleaning and washing cars.*—The car ought to be washed down as soon as it comes in, without giving the mud a chance to set. On no account should dirt, dust, or mud be brushed off. It must, in the fullest sense of the term, be washed off or else the paint work will be ruined. If a hose is available, it will be very useful in getting the mud off the under parts of the car, and will save a lot of time and labour.

In using the hose for the outside of the car (that is for the wheels and body work in general), the following points should be observed :—

(*a*) Care must be taken that the water does not go anywhere but where it is intended to. It should not be splashed about in every direction.

(*b*) A strong pressure of water from the nozzle is of considerable advantage in cleaning the underparts of the car, where the mud is generally heaviest, and in cleaning the underside of the mudguards.

(*c*) When dealing with the paintwork, however, a strong pressure of water is quite likely, in removing the gritty particles, to at the same time force them over the paintwork and scratch it. Apply the water with little force, but in plenty. If this is done when the car comes in wet the mud will be speedily and easily removed. If the mud has been allowed to dry, the water must be poured over it so as to soften it first; afterwards it will be gradually carried away as the water runs over it. On no account should the mud be rubbed off. Brushing or rubbing the mud off, even if it is wet, will cause scratching and deterioration of the paintwork.

(*d*) When all the dirt and mud has been soaked off, the surface can be gone over with a wet sponge, using clean water. After this has been done, the surface should then be dried off with a clean chamois leather.

(*e*) Oils and grease are bad for the paintwork, and care must be taken that neither petrol, paraffin or lubricating oil is allowed to remain on any part of the paintwork.

(*f*) When dealing with a car which is soiled with dust, the same care must be used in attempting to rub it off; the surface should be gone over first with a full sponge and finished off as before.

9. *Care of tyres.*—If the following points are attended to the life of tyres can be considerably increased :—

(*a*) All cuts, even surface cuts, require vulcanising. This keeps water out.

(*b*) Tyres must be kept up to pressure, usually about 60 lbs. per square inch.

(*c*) If possible keep two spare wheels so that repairs can be carried out on one while the other is ready for duty.

(*d*) Watch wheels for alignment. If a tyre shows abnormal wear look to the axle or distance rods.

(*e*) Do not apply brakes abruptly, except in emergency. A rapid "pull up" takes a good deal of mileage off a tyre.

10. *Removing and replacing tyres and tubes.*—To remove the air tube, loosen the security bolts as far as the wing nuts will go without removal. The external parts of the valve are next removed (care being taken to place any of the loose fittings in a safe place). The edge of the cover can then be pushed from under the lip of the rim and the lever inserted in positions a few inches on each side of a rim bolt, so that the edge of the cover can be raised over the rim. Special care must be taken not to damage the air tube. The levering must be repeated at intervals of about 6 ins. until the edge of the cover is brought over the rim all round. If the operator has to work single-handed, the best method is to use three levers. Two levers are inserted, and the wheel turned round so that one lever rests against the foot and the next against the leg of the operator. Both hands are then free to manipulate a third lever. Should the air tube be difficult to remove through sticking to the cover, it may be necessary to apply some petrol to the place. The cover, must, however, be allowed to dry thoroughly, and French chalk must be rubbed on afterwards, as petrol is very injurious to indiarubber.

To remove the valve, insert the curled end of the lever over the tube, pushing it across till it catches hold of the tyre on the opposite side of the rim. The cover can then be pushed up out of the way with one hand and the valve withdrawn with the other.

The inside of the cover should now be carefully felt for puncturing objects. The cover should also be cleaned thoroughly of any loose gritty material that may be inside. Afterwards a handful of clean French chalk should be put in and shaken round.

When inserting the new tube, see that it is first of all slightly inflated, and make certain that it is put in quite straight and is free from any twists, or kinks, which would be certain to cause trouble later on. When the tube is in position, first replace that part of the cover which is notched to fit round the valve, go round once more and see the air tube is straight, and then push up the valve and security bolts in order to allow the edges of the cover to fit into the lip of the rim. Next draw the valve and bolts down into position. The greatest care should be taken in using the tyre levers not to pinch or injure the air tube.

To completely detach a cover, insert the lever on the inner side of the wheel about 2 ins. away from a bolt. Lever up the bead of the cover from the rim, and then pull the bolt down so that the bolt head will be underneath the bead of the cover. Repeat this operation at each bolt. Next insert a lever from the inner side of the wheel right across the rim, and lever the tyre bodily off.

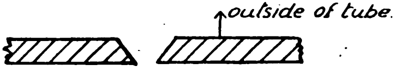
In putting on a new cover it will generally be found stiff to manipulate. The rim should be clean and free from rust. The levering should be repeated at smaller intervals, the hands being used in assisting to work the cover down to its

proper position. Sufficient French chalk should be used with a new cover and tube so as to prevent the two becoming stuck.

11. *Vulcanizing.*—Tyres and tubes of large dimensions cannot be satisfactorily repaired by patching. Therefore a system called "vulcanizing," by which repairs can be executed, is adopted. The system most generally in use is the Harvey-Frost, which is described in the following paragraphs :—

*Harvey-Frost system of vulcanizing.** (*a*) *Inner tube repairs.*—The edges of the puncture, or burst, must first be bevelled by means of a pair of scissors. This is done in order that a larger uniting surface may be provided for amalgamation with the new material.

The bevel should be cut thus :—



and not thus :—

Special care should be taken to carry the bevel well round the ends of the damage, in order to prevent the burst from extending.

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* This system can be used with considerable success in repairing aeroplane tyres and tubes.

The bevelled edges must then be well roughened by means of a rasp, in order to obtain a still better uniting surface.

Apply two coats of vulcanizing flux to roughened edges, allowing the first coat to dry before the application of the second coat. The flux enables the new material to amalgamate thoroughly with the old material of the tyre.

A sufficient quantity of vulcanizing compound must now be inserted into the cavity, and thoroughly pressed and rolled in by the aid of a "V" shaped roller. Before application, the compound should first be slightly warmed on the vulcanizer, as it then becomes softer and more plastic, and is much more easily worked. The utmost care should be taken to prevent any air or gas from being secreted when filling in the compound. Want of care on this point is likely to result in the newly introduced material becoming blown, or porous, and consequently not so strong as it would otherwise be. Do not press too much compound into the repair, as an excess of compound will force the lips of the repair open, and will result in a bulged and clumsy repair when vulcanized. The rolling should be done across the repair and not in the direction of the burst.

The projecting compound is now trimmed level with the surface of the tube by means of a wet knife. The superfluous flux and compound can be cleaned off with a sponge or cloth damped with naphtha.

The repair is now ready for the vulcanizer. It is recommended that the vulcanizer should be filled with water to the correct level each time it is used, as this reduces to a minimum the chance of any mishap through this important operation being overlooked. Pour in the water at the water-

filling valve until it overflows at the water-level valve. Then close both valves and light the burner. After 25 to 30 minutes (the length of time being governed by the heating apparatus in use), a steam pressure of 60 lbs. per square in. will be generated, and this pressure must be uniformly maintained throughout the whole of the operation.

The damaged tube, having been previously prepared as explained, is now placed on the vulcanizer, with the part under treatment facing the heated surface and with a piece of gas absorbent cloth intervening. On top of the tube is placed the nearest size pad which is sufficient to cover the area being treated. By means of the screw press, the pad presses the tube into firm contact with the vulcanizer. Only such pressure as can be obtained by screwing the press with thumb and finger should be used. In no case should the pad be allowed to press on the folded edges of the tube.

Time table for vulcanizing repairs in tubes.—In vulcanizing there is considerable scope for individual discretion, but the following table can be taken as a basis on which to work :—

Thickness of tube.	Time (at 60 lbs. pressure).
$\frac{1}{16}$ in.	9 minutes.
$\frac{1}{12}$ "	10 "
$\frac{1}{10}$ "	13 "
$\frac{1}{8}$ "	17 "
$\frac{1}{6}$ "	19 "

It should be borne in mind that the length of time for curing is not governed by the width or length of the repair, but by the depth of the new material introduced in making the repair. The above time table applies to repairs done with Harvey-Frost Buff Compound.

The following is the time table for repairs done with Harvey-Frost Plastene :—

Thickness of tube.	Time (at 45 lbs. pressure).
$\frac{3}{64}$ in.	6 minutes.
$\frac{1}{16}$,,	7 ,,
$\frac{1}{12}$,,	8 ,,
$\frac{1}{10}$,,	10 ,,
$\frac{1}{8}$,,	13 ,,
$\frac{1}{6}$,,	15 ,,

In dealing with large open bursts where a portion of the tube is missing, a somewhat different method is adopted. Instead of filling in the burst with the vulcanizing compound, it is simpler, and more economical, to replace the missing portion with a piece of rubber. Odd pieces of old tubes can be utilized for this purpose. The first step is to find a piece of old tubing about the same thickness as the tube needing repair, and to cut a piece from it as nearly as possible the same size and shape as the burst. Having done this, a bevel is cut on the edge of the burst and also on the edges of the piece of old tube being used. The edges are then roughened in the same way as an ordinary tube repair. The piece of tube to be inserted should be of such a fit that there is only the bevelled edge separating it from the tube being repaired. After two coats of vulcanizing flux have been applied, a sufficient quantity of vulcanizing compound is inserted into the cavity and thoroughly pressed and rolled in the same manner as an ordinary repair.

(*b*) *Cover repairs. Surface repairs.*—A cut, if neglected, means rapid decay. In the first place, cut and bevel the hole and then roughen it. When this has been done, the cut should be thoroughly cleaned all round with naphtha and coated with

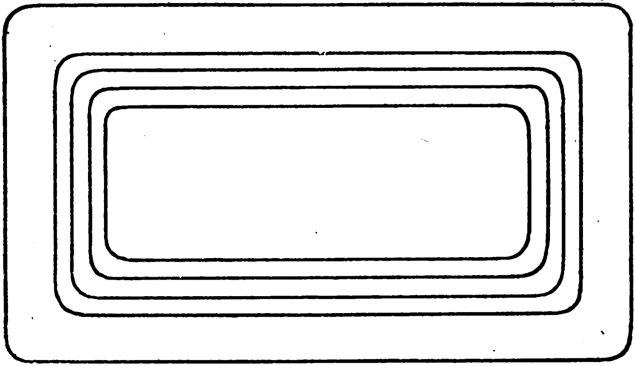
two coats of vulcanizing flux. After this has been allowed to thoroughly dry—a very important matter—the space should be filled in with vulcanizing compound, the latter being thoroughly pressed and rolled in. The projecting compound is now trimmed off level with the surface of the tyre. The tyre is now ready for the vulcanizer and should be placed centrally on the mandrel and secured by means of tape at both ends. An interchangeable face is then selected as most suitable for the work in hand and fixed to the steam heated pad. The steam heated pad is next clamped into position with a piece of wet cloth between the face and the prepared work. Great care must be taken to see that the face is in good contact with the prepared portion. In case the face does not come in close contact with the part of the tyre under repair, it should be packed with a piece of sheet lead. When the pad has been fixed into position, the steam supply valve is opened. The prepared work is then left to vulcanize for about 30 minutes at 60 lbs. steam pressure. To be sure that there is no condensation of steam in the pad, the petcocks should be opened once or twice during the operation.

Repairing a burst cover or a defect in the canvas foundation.—A burst or cut which has penetrated the canvas foundation should be treated as follows :—

Take, for instance, a cover, the foundation of which is comprised of four layers of canvas. The first layer of canvas should be cut away for about 4 ins. each side of the burst, the second layer 3½ ins., the third layer 3 ins., and the fourth layer 2½ ins. This is done on the stepping out system.

The illustration shows four pieces of double proof canvas resting on a piece of single proof.

Top layer.



The pieces of old canvas which have been removed should be used as templates to cut the pieces of double proof canvas to. A final piece of single proof canvas is cut to cover over all, and should be about the length of the mandrel, and wide enough to reach to within ½ in. of the beads. Now proceed with the application of several coats of vulcanizing flux cement, allowing each coat to dry separately until a film of rubber is formed on the canvas. When the tyre is perfectly dry the canvas should be placed in position, each layer being damped with naphtha to make the surface adhesive. If there are any crevices, hollows, or uneven surfaces exposed before the first layer of canvas is applied, they must be filled in with compound so as to make a solid and even

foundation to build upon. Similarly, in placing the layers of canvas in position, any small crevices should be filled in with narrow strips of compound. The preparation is now complete on the inside of the cover, and a mandrel most suitable for the work is placed inside at the part being treated. A piece of cloth, French chalked, must intervene between the inside of the cover and the mandrel, so as to keep the surface clean.

The cover is then either clipped or taped on to the mandrel, the damaged portion on the outside being left exposed. After the necessary connecting up has been done, the steam supply valve to the mandrel is then opened. The petcock should also be left open until dry steam escapes, when it should be closed and the prepared work allowed to vulcanize 30 minutes at 60 lbs. The repair is then finished.

It is most essential that all covers, before being treated, should be perfectly dry.

Inside repairs.—In some cases the trouble is only on the inside of the tyre. In this case the stepping should only be carried out as far as the trouble extends, the part cut away being replaced with new canvas. An extra support is added by stretching a piece of single proof canvas from bead to bead and making it about 2 or 3 ins. larger than the largest piece of canvas inserted. This is vulcanized by means of the mandrel. No external heat is required.

(*c*) *To judge perfect vulcanizing.*—The perfect curing, or vulcanizing, of a tyre repair is best tested by the thumb nail after the repair has cooled.

Should an impression be left on the part vulcanized after being indented by the thumb nail, it is a sure sign that it is under-cured, or under-vulcanized. The repair should again be applied to the vulcanizer for a short time. If, on the other

hand, the repair feels hard, brittle, and entirely irresponsive to the touch, it is a sign that it is over-cured.

This state should by all means be avoided, as it is preferable to under-cure rather than over-cure.

APPENDIX I.

Gradient Velocities.*

Beaufort number.	Gradient wind velocity (miles per hour).	Distance apart in nautical miles of $\frac{1}{10}$ in. Isobars.						
2	5	520	540	560	580	600	620	640
3	10	260	270	280	290	300	310	320
4	15	170	180	190	190	200	210	210
5	20	130	140	140	140	150	150	160
6	25	100	110	110	120	120	120	130
	30	87	90	93	97	100	100	110
7	35	75	77	80	83	85	88	92
8	40	66	68	70	72	75	77	80
	45	58	60	62	64	66	69	71
9	50	52	54	56	58	60	62	64
10	55	48	49	51	53	54	56	58
	60	44	45	47	48	50	52	54
11	65	40	42	43	44	46	48	49
	70	38	39	40	41	43	44	46
	75	35	36	37	39	40	41	43
12	80	33	34	35	36	37	39	40
	85	31	32	33	34	35	36	38
	90	29	30	31	32	33	34	36
	95	28	28	29	30	31	33	34
	100	26	27	28	29	30	31	32
	110	24	25	25	26	27	28	29
	120	22	23	23	24	25	26	27
	130	20	21	21	22	23	24	25
	140	19	19	20	21	21	22	23

	Pressure and Temperature.													
	†In.	°F.	In.	°F.	In.	°F.	In.	°F.	In.	°F.	In.	°F.	In.	°F.
	31	28	31	44	31	60	31	77	—	—	—	—	—	—
	30	13	30	27	30	43	30	60	30	78	30	97	—	—
	—	—	29	11	29	26	29	43	29	60	29	79	29	99
	—	—	—	—	28	10	28	25	28	42	28	60	28	79
Col. Nos.	1		2		3		4		5		6		7	

* Advisory Committee for Aeronautics Report, No. 9
† In.=Inches of mercury. °F.=Degrees Fahrenheit.

Gradient direction is along the isobars, with the low-pressure on the left hand.

To find gradient wind from a weather chart by the aid of the above table, proceed as follows (typical case):—

The observer is at "A" and in latitude 53°, and wishes to find the gradient wind. He takes the two isobars on the map on either side of him and measures the distance between them. He finds this to be 140 miles. From the map he also notes that the atmospheric pressure is 30 ins. and the temperature 60° Fahr. At the bottom of the table he finds that the pressure and temperature nearest to his readings appear in column 4. He then looks up column 4 (distances) and finds that the gradient wind corresponding to the distance between the two isobars is 20 miles per hour.

The table is made out for latitude 53°. For latitudes greater than 53° subtract 1 per cent. from the gradient velocity found in the table, and vice versa.

APPENDIX II.

BEAUFORT WIND SCALE.

Beaufort number.	Description of wind.	Mean wind force in lbs. per square ft. at standard density.	Equivalent velocity, miles per hour.	Beaufort number.
0	0	0	0	0
1	Light breeze	0·01	2	1
2		0·08	5	2
3		0·28	10	3
4	Moderate breeze	0·67	15	4
5		1·31	21	5
6	Strong wind	2·3	27	6
7		3·6	35	7
8	Gale forces	5·4	42	8
9		7·7	50	9
10	Storm forces	10·5	59	10
11		14·0	68	11
12	Hurricane	above 17·0	above 75	12

APPENDIX III.*

VARIATION OF VELOCITY OF THE WIND WITH HEIGHT DURING THE DAY TIME.

Miles per hour.

Surface at Upavon.	500 ft.	1,000 ft.	2,000 ft.	3,000 ft.	4,000 ft.	5,000 ft.
5	7	8	8	8	10	13
10	15	18	18	18	19	20
15	21	26	28	29	29	29
20	28	34	37	40	40	40
25	35	43	47	49	50	50

* These tables are averages obtained by experiment at Upavon. The actual figures will vary at different places, but the general tendency remains the same.

Variation of Velocity during the Night, late Evening, and early Morning.

Surface at Upavon.	500 ft.	1,000 ft.	2,000 ft.	3,000 ft.	4,000 ft.	5,000 ft.
2	7	8	8	8	10	13
5	12	15	15	15	15	16
10	20	22	22	22	22	22
15	25	30	30	31	31	31
20	29	34	38	40	40	40
25	35	43	47	49	50	50

Variation of Direction of Wind with Height.

Wind veers with increasing height, *i.e.*, upper wind blows from a point to the right (or in a clockwise direction) of that from which the surface wind blows. The amount of the deviation from the direction of the surface wind is given below:—

—	Surface.	500 ft.	1,000 ft.	2,000 ft	3,000 ft	4,000 ft.	5,000 ft.
Deviation to right in degrees ...	0	5	10	16	19	20	21

Hence the following surface winds may be expected to change with height to the winds shown in the following table :—

Surface.	500 ft.	1,000 ft.	2,000 ft.	3,000 ft.	4,000 ft.	5,000 ft.
N.	N. ½ E.	N. by E.	N. by E. ½ E.	N. by E. ¾ E.	N.N.E.	N.N.E.
E.	E. ½ S.	E. by S.	E. by S. ½ S.	E. by S. ¾ S.	E.S.E.	E.S.E.
S.	S. ½ W.	S. by W.	S. by W. ½ W.	S. by W. ¾ W.	S.S.W.	S.S.W.
W.	W. ½ N.	W. by N.	W. by N. ½ N.	W. by N. ¾ N.	W.N.W.	W.N.W.

APPENDIX IV.

Glossary of some Aeronautical Terms.

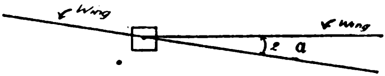
A.

Air screw ... ... See "Screw."

Altimeter ... ... An instrument used for measuring height.

Anemometer ... An instrument for measuring the speed of the wind, and also, in some cases, for recording the direction of the wind.

Angle, dihedral ... In geometry, the angle between two planes. In an aeroplane, the angle between two wings—usually given as the small angle *a*.



Angle, gliding ... The angle relative to a horizontal line (fixed in the air) at which an aeroplane descends with the engine cut off.

Angle, of incidence The angle a wing makes with the direction of motion relative to the air. The angle is usually measured between the chord of the wing (front and rear spars) and the direction of motion.

Anti-drift wires	...	See "Wires."
Landing wires	...	See "Wires."
Anti-warp wires	...	See "Wires."
Attitude ...	...	Posture of a body. Often used to define an aeroplane's, or wing's, position with regard to its direction of motion through the air.

B.

Back, to ...	...	In reference to the wind—to change direction counter-sunwise.
Balancing flaps	...	Thin and flat or slightly curved structures used for balancing an aeroplane, or causing it to roll about its longitudinal axis. The French word "aileron" is sometimes used in English for this.
Ballonnet ...	...	A word taken from the French meaning "a little balloon," and exclusively limited to an interior bag, containing air, within the envelope of an airship.
Bank, to ...	...	To roll for the purpose of turning, to raise the outer wing for the purpose of turning.
Barograph ...	...	A recording barometer, the charts of which can be calibrated for showing pressure or height.
Barometer ...	...	An instrument used for measuring the pressure of the atmosphere.

Body ... ... Of an aeroplane—the main frame, its fairings and coverings; that part which usually contains the engine, crew, tanks, &c., and to which the wings and other organs are attached. The French word "fuselage" is sometimes used for body.

Bracing ... ... A system of struts and ties, to transfer a force from one point to another.

Bracing, drift ... The system of bracing used to transfer the drag or head resistance of the wings to the body of an aeroplane.

Burble point ... That point on the lift curve of a wing which is reached when the angle of incidence has become so great that the stream lines change from a steady to a fluctuating and eddying state, causing the lift to fall and the drag to increase.

C.

Cabane ... ... A French word to denote the arrangement of struts projecting from the body to which landing wires, anti-warp or warp wires of a monoplane are attached.

Cabre ... ... The attitude of an aeroplane whic is flown at a large angle of attack on the air. In sailors' parlance, "down by the stern."

Camber	The slight convexity of a deck (or wing). The camber is usually measured in terms of height above the chord.
Camber, top surface	The camber of the upper surface of a wing.
Camber, under surface	The camber of the under surface of a wing.
Chord	The straight line joining the ends of an arc. The straight line joining the ends of a fore and aft cross section of a wing.
Control lever ...	On an aeroplane, the lever with which the pilot controls the machine. It usually works the warp and the elevator. On one particular aeroplane the word "cloche" used to be employed; this is a French word meaning "bell." A bell-shaped piece of aluminium is used on the control lever of Bleriot aeroplanes, and the word has erroneously come to mean control lever.

D.

Directional stability	See under "Stability."
Dihedral angle ...	See under "Angle."
Dive	To descend steeply. Sometimes the expression "vol pique" is used in English for a steep glide or descent.

Dope, to	To paint a fabric with a dope, often a varnish of cellulose base which tends to tighten and protect wing fabrics.
Drag	Obstruction to progress, the head resistance or drift.
Drift, to	To be carried as by a current of air or water.
Drift, side	Drift to port or starboard. The distance moved at right angles to the longitudinal axis of the aircraft in a sideways direction. Also used for the velocity of such movement.
Drift bracing ...	See under "Bracing."
Drift, of a craft ...	The ship's or aircraft's leeway due to currents.
Drift wires	See under "Wires."

E.

Elevator	A flat or slightly curved structure, set in a horizontal plane and hinged on an athwartships line. It is used for steering and balancing in the up and down directions.

F.

Fairing	A piece added to any structure to improve its fairness and shape, and incidentally to reduce its head resistance or drag.

Fins	Thin and flat or slightly curved organs, set parallel to the normal direction of motion of an aircraft. In an aeroplane, always normally vertical.
Fins, stabilising ...	Fins used on an airship to prevent her from yawing and turning side on to her direction of motion, and also to prevent her from pitching.
Flaps, balancing ...	See under "Balancing."
Flaps, wing... ...	See under "Wing."

G.

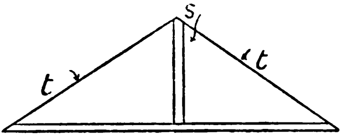
Gap	The distance between the upper and lower wings of a biplane.
Glide, to	Of an aeroplane, to descend with the engine cut off.
Gliding angle ...	See under "Angle."

I.

Incidence, angle of...	See under "Angle."

K.

King post	A strut "s" in connection with two ties "t" to strengthen a wing spar on either beam.



L.

Lateral stability ...	See under "Stability."
Leading edge ...	The forward edge of a wing.
Lee, leeward, leeway	Away from the wind ; shelter ; lateral drift of a ship to lee or leeward.
Lift, to	To give an upward direction. To force in an upward direction.
Lift	The rise of a ship on a wave. In an aircraft the upward force in the direction perpendicular to the direction of motion relative to the air.
Lift bracing ...	See under "Bracing."
Loading	The weight carried per unit area of sustaining surface.
Longitudinal stability	See under "Stability."

N.

Natural stability ...	See under "Stability."
Normal	Perpendicular to the direction of flight, or of an air stream.

P.

Pitch	The distance forward that a screw propeller or tractor would travel in one complete revolution if there were no slip, *i.e.*, if it were moving in a thread cut in a solid.
Pitch, to	To plunge in the longitudinal direction (nose up or nose down).

Pitot tube ... ... A tube with open end facing the wind, used as part of the pressure head of a velometer.

Pressure head ... A combination of Pitot tube and static pressure tube to collect the air pressure whose difference is used to measure air speed in the velometer.

Pressure tube, static A tube, usually with holes in its side, past which the air flows so that the pressure inside the tube equals the pressure of the air, used as part of the pressure head of a velometer.

Propeller ... ... An air screw which pushes from behind.

Pylon ... ... A Greek word meaning "a post." In aeronautics it is used for a post marking a racing course, or a post projecting from a body to take a wire from the wings. A preferable English terms is a "mast."

R.

Rib ... ... Of a wing—a light fore and aft member which carries the fabric and gives it the proper cross section.

Roll, to ... ... To turn about the longitudinal axis.

Rudder ... ... A flat, or slightly curved, thin structure hinged to a craft so that it can be turned to one side or the other athwartships—used for steering in the horizontal plane.

Rudder post ... The post to which the rudder is hinged.

S.

Screw	On an aeroplane—besides its use as a part holding other parts together, this word is used for the screw-shaped part, which, when turned by the engine, forces the machine through the air. Such screws are used either to pull or push an air-craft and are respectively known as tractor screws or propeller screws, the word screw being omitted for brevity.
Side drift	See under "Drift."
Side slip, to ...	To move fully or partially sideways with respect to the air.
Skid	A piece of timber serving as a support or inclined plane.
Skid, to	To slip or slide forwards or backwards on the ground.
Slip	The difference between the actual progress of a screw propeller or tractor in one revolution and its pitch.
Span	The full extent from end to end. The distance from wing tip to wing tip.
Spar	A long piece of timber. In a wing, either of the beams which run athwartships and transfer the lift from the ribs to the frame and bracing.
Stability, direction	Exists when the aeroplane tends to head up into the wind.

Stability, lateral ...	Exists when the transverse axis of the aeroplane tends to return to the horizontal.
Stability, longitudinal	Exists when the longitudinal axis of the aeroplane tends to return to the horizontal.
Stability, natural ...	Exists when the aeroplane tends to return to its normal attitude of flight, and when oscillations about that position tend to decrease without the application of the controls. Sometimes described as inherent stability.
Stabilising fins ...	See under "Fins."
Stagger	Of wings—when the wings of a biplane are set with the upper one slightly ahead of, or in rear of the other. The stagger is measured by the angle made with the normal vertical by a line joining the leading edges.
Static pressure ...	See under "Pressure."
Steer	To guide by helm in a specified direction.
Strainer	A gauze or other device for preventing the ingress of solid particles into oil, water or petrol tanks, or into the carburetter, or into the pipes. This term should not be used for a turnbuckle or wire tightener.
Streamline	The path of a particle of fluid with respect to a solid body.

Strut	... ...	A piece of wood or metal intended to take pressure in the direction of its length.

T.

Tail	...	The after part of an aircraft.
Tail, lifting	...	A tail in which a horizontal plane is set to carry a proportion of the weight of the aeroplane.
Tail, non-lifting	...	A tail in which a horizontal plane is set edge on to the direction of motion so that it carries none of the weight of the aeroplane.
Tail plane ...	...	A flat or slightly curved structure, set on the tail nearly in the horizontal plane. It is usually fixed, and by receiving wind pressure on its upper or lower surface is intended to provide a righting moment. The French word "empennage" is sometimes used. It seems to mean tail plane and elevator, but is a vague term alluding to the feather equipment of an arrow, and doubtless also includes any vertical tail fin as well as horizontal plane.
Tie ...	...	A structural member intended to be in tension.
Top surface camber		See under "Camber."

Torque propeller ... The tendency of a propeller or tractor to turn an aeroplane about its longitudinal axis in a direction opposite to that in which the propeller or tractor is revolving.

Tractor ... ... An air screw which pulls from in front.

Trailing edge ... The rear edge of a wing.

Turnbuckle ... A device for tightening a wire, generally by a right and left-handed thread. The word "strainer" should not be used, as this is allotted to the filtering device employed for filling tanks and intercepting solid particles.

U.

Undercarriage ... The organ of an aircraft which enables it to run along the ground and to absorb the shock of landing. It includes the wheels, skids, shock absorbers and their framework of struts and wires. The French word "chassis" is sometimes erroneously used for undercarriage.

Under surface camber See under "Camber."

V.

Veer (of the wind) ... To change direction sunwise (clockwise).

Velocity of side slip The speed with which the craft slips sideways with respect to the air.

Velometer	Name of an instrument for measuring the speed of aircraft through the air by means of a pressure gauge.

W.

Warp, to	Of wood, to bend, generally across the grain. Of a wing, to bend so that the outer end or the whole of the back spar moves up or down.
Weather	Towards the wind—in the expression "the weather side."
Wing flaps	Balancing flaps hinged to the trailing edge of the wings. The French word "ailerons" is sometimes used in English for this.
Wings	The main supporting organs of an aeroplane. A monoplane has two wings, a biplane four.
Wires, anti-drift ...	Wires pulling in the contrary direction to the drag wires to keep them taut, and to keep the wing in shape when the aeroplane is on the ground.
Wires, landing ...	Wires used to take the weight of the wings when the aeroplane is standing on the ground. Sometimes called anti-lift wires.
Wires, anti-warp ...	Wires used to take the weight of the back wing spar on the ground. They must be connected across from wing to wing so as to allow the wings to warp. Sometimes called compensating wires.

Wires, drift, drag ... Wires used in the bracing of an aeroplane to transfer the drag of the wings to the body.

Wires, flying ... Wires used for transferring the lift of the wings to the body or to another part of the structure. Sometimes called lift wires.

Wires, warp ... Wires used to take the lift of the back wing spar and to move its outer end up and down so as to warp the wing.

Y.

Yaw, to ... ... To turn the longitudinal axis of the aircraft away from the direction of the air course followed, *i.e.*, with respect to the air alone, since the land has nothing to do with it.

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